A Clinical and Morphological Study of the Neonatal Thoroughbred Foal's Eye.

VOLUME I

By

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SUMMARY.

Despite the huge increase in scientific knowledge and understanding of the equine neonate which has taken place in the last 10-15 years, little attention has been paid to the eye. This morphological survey of neonatal Thoroughbred foals was undertaken to define the following: the normal appearance of the eye in the neonate; to highlight the differences between the neonatal and adult equine eye; document the route and time-scale of the development from one to the other; record the incidence and type of anomalies that occur and to distinguish these from true abnormalities; and finally, to study the incidence, morphology, reabsorption and long term effects of neonatal retinal and/or scleral haemorrhages and thereby, suggest an aetiology.

Detailed ophthalmoscopic examinations were carried out on 169 randomly selected neonatal Thoroughbred foals born in two separate regions of the U.K. and one in New Zealand. A standardised examination was carried out and recorded using words, illustrations and photographs. Each foal also received a detailed clinical examination. Details of the mother's reproductive, gestational, parturitional and post-partum history were also recorded. Examinations were carried out within 96 hours of birth and repeated as necessary. Recorded data was subjected to an extensive statistical analysis.

The recording and analysis of the data from the mare and foal allowed the generation of a database for each foal so that it could be identified and traced, if required, in later life. An assessment was made of the gestational and parturient factors that might affect the development of the neonatal foal and particularly its eyes. Foal disease processes that may directly or indirectly contribute to variations in the morphology of the neonatal eye were also defined.

All the foals in the survey had eyes open at birth and 98% had normal vision at the time of first examination. The most effective way of testing vision in the neonate was close observation of the foal in a box or nursery paddock. The menace reflex was absent in 96.5% of foals and, therefore, of little use in neuropathological testing, whereas 96% of foals had a positive pupillary light reflex, usually of a slow or sluggish nature.

The normal appearance of the eyelids of the foals in this survey was similar to previous descriptions in the foal and adult, with long and dense upper cilia, and short, rather sparse lower cilia. The normal pattern of vibrissae was

long and betwen 1 and 5 in the upper eyelid, and long and between 6 and 10 in the lower eyelid. 5% of foals had eyelid abnormalities, the majority of which were secondary entropion. The appearance of the conjunctiva in the neonatal foal differs little from the adult, and conjunctival differences between the foals in this survey partially correlate with coat and nictitans colour.

The incidence of subconjunctival (scleral) haemorrhages in this survey was 8.3% and did not change with the period after birth when the first examination was carried out. There were no sex or eye distribution affects and the haemorrhages were not associated with any neonatal disease or abnormality. All haemorrhages were fresh, red and resolved within 4-10 days of birth. Most haemorrhages were present dorsal or dorso-nasally, and extended up to the limbus. The main factors involved in the pathogenesis of the haemorrhages seem to be increased peripheral venous pressure and direct compressive blunt trauma to the orbit during birth canal passage.

The cornea of all normal foals was clear, oval and broader nasally. 67% of foals had a scleral shelf, usually dorsal and ventral. 62% also showed the presence of the pectinate ligament corneal insertions on the temporal and nasal aspects of the eye, and these are considered normal in the foal. Although the incidence of congenital corneal abnormalities was low, a case of congenital corneal vascularisation was recorded, this being only the second in the literature.

The vast majority of foals had a dark brown or grey-brown iris colour with tan mottling towards the periphery and grey iridescent bands, especially towards the pupillary margin. The resting pupil was approximately 75% of maximal dilation, usually of a circular or broadened oval shape. The size and shape of the pupil were related to the examination time. Post pupillary light reflex pupil sizes were 5-15% of dilation smaller and of an oval shape, with the degree of change depending on the age of the foal. Anisocoria was present in 4 foals, including one with NMS, and return to clinical normality mirrored the resolution of the anisocoria. All foals in the survey had dorsal corpora nigra and 74% ventral structures. Dorsal corpora nigra were usually prominent and of normal size, whereas ventral structures were small and difficult to detect. Collarette tags of the anterior pupillary membrane were common and considered of no pathological significance.

The lens suture pattern was visible in 82% of foals, but detection of the anterior suture was difficult to confirm. 25% of foals had posterior pupillary membrane remnants and it was concluded that they represent a normal variation in the resorption of the foetal lens vascular system. 4 foals had lens cataracts, all associated with other ocular abnormalities, but no visual deficits.

Over 80% of foals had some part of the hyaloid system present, usually bilaterally, with its completeness, colour and character related to the time since birth. The presence in the neonatal period of a hyaloid structure is not considered to be abnormal and confirms the more prolonged pattern of resolution in this species.

The fundi of the neonatal foals in this survey were considered to be similar to the adult in many features. The optic disc was more red and homogenous than the adult, with an enormous variation in appearance (size, shape and character). Bilateral symmetry was common. 14 foals had an optic disc with papilloedema or one that was difficult to bring into focus using the ophthalmoscope. There was a higher incidence of abnormal foals in these groups.

In this survey there appears to be a relationship between reddening of the optic disc, retinal vessel congestion and tortuosity, papilloedema and retinal haemorrhages, and a common pathophysiology is explored. The tapetal and non-tapetal fundic appearance varied enormously but differed little from the adult. The incidence of congenital abnormalities of the fundus was high in this survey, but only one foal had apparent visual deficits. Atypical colobomata were common but appeared, from the results in this survey, to be incidental findings.

The incidence of retinal haemorrhages in this survey was 16%, with 90% of foals examined within 48 hours of birth. No connection between retinal and subconjunctival (scleral) haemorrhages or other ocular pathology, except papilloedema, could be established. Eye distribution was similar, but increased numbers of female foals were affected. The number, type, distribution and stage of development of the haemorrhages was recorded. Bilateral and fundic distribution, and type of haemorrhage are related to numbers of haemorrhages. The level of the retinal haemorrhages and their source/s within the fundus are discussed, but confirmation will await histological study. The rate of resolution of haemorrhages is rapid (< 10 days), unrelated to number or type, and occurs in a distinct pattern. This survey confirms that there are no long term ophthalmoscopic, visual or neurological effects of neonatal retinal haemorrhages in the foal. The pathogenesis of the haemorrhages in the foal appears complicated, interrelated and multiple with individual variation in significance of various factors. The major pathways probably include intracranial and intravascular pressure effects, with the addition of anoxia/asphyxia and individual anatomic factors.

Dedication.

Too my sons Robert and David.

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TABLE OF CONTENTS.

VOLUME I

VOLUME II

LIST OF TABLES.

CHAPTER 1.

INTRODUCTION.

1.1. THE NEED FOR A NEONATAL FOAL STUDY.

In the last decade there has been a marked interest in the physiology, pathology and care of the neonatal foal. Many scientific articles and books have been published on basic and applied aspects of care of the young foal in an attempt to disseminate this rapidly gained information right through the veterinary world. Much of the drive towards this admirable goal has come, as is often the case, through economic considerations. Some newborn foals can be valued in 10's or 100's of thousands of pounds, leading to pressure from owners, stud personnel, and insurance companies for better results in treating neonatal foals. Even where foals' values are not measured in such inflated terms, expectations of owners continue to increase, placing upon the veterinary profession the need for greater knowledge of all aspects of neonatology.

One aspect of the neonate that has not received as great attention as it might, is the eye. Although equine ophthalmology has a history stretching back 60-70 years, especially in Eastern and Central Europe, it is only in the last two decades that concerted and co-ordinated scientific study has increased our understanding of this important subject. Much of the study concentrated on the mature horse with little realisation that the neonatal and young foal eye did not mirror the adult eye in structure or function. This was particularly highlighted when veterinary surgeons began to be asked on a regular basis to examine both sick and healthy foals on intensively managed stud farms. Routine neonatal health checks and insurance examinations require a complete examination of the eyes, and many veterinary surgeons found themselves unable to give sensible opinions. This problem was further compounded by the lack of scientific literature available on the subject.

It became clear that a detailed study of the neonatal foal's eye was required both to document the normal morphology and development, as well as cast light upon perplexing areas such as retinal and scleral haemorrhages.

1.2. REVIEW OF LITERATURE ON PREVIOUS ADULT AND FOAL EYE SURVEYS.

The first results of surveys of equine eyes were published in German by Schnelle (1951) and Brandenburg (1952a and b). Both authors undertook an ophthalmic survey in foals born blind. Brandenburg (1952a) also carried out pathological investigation of some of the material. No attempt was made to examine and compare findings with visually normal foals.

Later, a number of authors published work on the adult equine eye, some based on a survey of a randomly selected population, others using accumulated data from a period of examining normal and pathological equine eyes. All of them concentrated on the fundus of the horse where the greatest variation occurs (Formston, 1956; Andrasic, Marolt, Frank, Vukelic, Cermak and Sankovic, 1963; Ammann and Muller, 1968; Gelatt and Finocchio, 1970; Gelatt, 1971; and Barnett, 1972).

Further work covering the whole equine eye in the adult horse has been published since the early 1970's, mainly in various editions of the standard ophthalmological and equine textbooks (Gelatt, 1972 and 1974; Riis, 1981; Gelatt, 1982; Schmidt, 1984; Barnett and Bedford, 1985; Bedford, 1985; Lavach, 1990; Davidson, 1991; Rebhun, 1991; Roberts, 1992a). Recently, three articles published in the second Equine Veterinary Journal supplement on equine ophthalmology have provided comprehensive information on the structure, function, normal variants, and pathology of the equine fundus (Crispin, Matthews and Parker, 1990; Matthews, Crispin and Parker, 1990a and b).

Barnett (1975) was the first to report the results of a survey of newborn Thoroughbred foals' eyes, albeit of an undisclosed number and age. The normal eye was described, with emphasis on the differences from the adult. Eye changes were described in the convulsive foal syndrome (Neonatal Maladjustment Syndrome NMS) (Palmer and Rossdale, 1975 and 1976), which included retinal haemorrhages and anisocoria. Other congenital abnormalities described included microphthalmos, entropion, lens coloboma, and a case of persistent pupillary membrane.

Koch (1977) and Koch, Cowles, Schmidt, Mayo and Bowman (1978), examined 82, mainly normal, Thoroughbred foals between 1 and 30 days of age, for evidence of ocular disease. All examinations took place in a darkened stall using both indirect (otoscope) and direct ophthalmoscopy. No artificial dilation was used. The authors concluded that the incidence of congenital orbital, lid, conjunctival and corneal disease was low in their survey. They noted ventral corpora-like tissue bilaterally in 24 foals and suggested that these represented a normal developmental change in the iris. 3 foals had unilateral posterior polar cataract involving the Y suture. Posterior Y suture opacities and remnants of the hyaloid system were described as common. Most of the changes noted in the survey were retinal, with what are described as "spots" in the pigmented portion of the fundus, observed in 21 foals. These were labelled as atypical coloboma, but no pathological confirmation was provided. Other changes included flattening of the optic disc inferiorly or superiorly in both eyes.

Latimer, Wyman and Hamilton (1983) examined 144 foals of three breeds (41 Saddlebreds, 50 Standardbreds, 53 Thoroughbreds) in order to define variations of the normal eye and adnexa in foals of these three breeds. The average age of the foals examined was 9.4 weeks with a range of 5 days to 19.5 weeks, and therefore none of the foals could be described as neonatal. Only clinically normal foals were examined using a focal light beam, hand-held biomicroscope and indirect/direct ophthalmoscopes. All foals had a mydriatic instilled into each eye, after menace and pupillary light responses had been evaluated. The results of the study were described as being generally in ageement with previous ocular descriptions of the foal (Barnett, 1975; Koch *et al*, 1978). The authors were unable to confirm the pupillary shape and response in the newborn foal because of the older type of foal examined. Few ocular variations appeared breed specific. Variations in fundic appearance were mainly related to tapetal colour and optic disc configuration. The focal non-pigmented spots seen in the non-tapetal fundus, as reported by Koch *et al* (1978) were found. Superficial corneal opacities were observed in five Thoroughbred foals and were the most frequent ocular abnormality noted in the study. The authors concluded that their study confirmed the low incidence of congenital ocular disease in the foal.

Roberts (1992b) using information from computer records of patients seen at Colorado State University Veterinary Teaching Hospital between 1972 and 1991, found that 5.3% of equine ocular problems were neonatal in nature (113 foals). 33.6% of these were cataracts, 18.6% retinal detachment and uveitis, 8% nasolacrimal atresia, 7.1% entropion, 7.1% microphthalmia, 7.1% persistent pupillary membrane, 3.5% congenital stationary night blindness and 3.5% retinal dysplasia.

Other than these 4 studies no other survey of foals' eyes has been published. The so-called neonatal foal survey published by Roberts (1992b) was based on a referred population and the foals examined were not all neonates. Some older foals were examined and their abnormalities classified as of neonatal origin. This present survey is the first to examine, in detail, neonatal foals randomly selected from a normal population. Two chapters have been published on neonatal ophthalmology in textbooks (Latimer and Wyman, 1985; Whitley, 1990), and one on congenital ocular defects in foals (Munroe and Barnett, 1984). These provide a synopsis of the current state of knowledge of the normal and abnormal eye of the neonate.

The incidence and type of congenital ocular defects seen in the horse were reported in a series of papers published in the 1970's (Priester, 1972; Keller, 1975; Huston, Saperstein and Leipold, 1977). Priester (1972) described the ocular defects by species (cattle, horses, cats and dogs) and breed, for the 9 most frequently occurring defects, and by species for other defects. He also investigated the independent effects of sex and breed on the risk of defects. Huston *et al* (1977), in a paper on all congenital defects in foals, described the individual ocular defects with their aetiology and frequency, where known, and also noted diagnostic aids and associated defects. Keller (1975) described, in a short paper, the ocular defects in Arab horses.

More recently, Crowe and Swerczek, (1985) and Leipold, Saperstein and Woollen (1990) provided excellent reviews of many congenital defects in foals, including ocular disorders.

1.3. AIMS OF THE SURVEY.

The present morphological survey of randomly selected Thoroughbred foals was originated in order to try and answer some of the questions, regarding the neonatal foal's eye, which were being posed to the author and colleagues on a regular basis.

Firstly, it was proposed to define the normal appearance of all of the neonatal Thoroughbred foal's eye. Secondly, to highlight the differences between the neonatal and adult equine eye and the way, and timescale, in which change occurs from one to the other. Thirdly, to record the incidence and the type of anomalies that occur in the neonatal equine eye and to distinguish these from true abnormalities or pathology. Finally, to study the incidence, morphology, reabsorption and long term effects of neonatal retinal and/or scleral haemorrhages. By relating these findings to clinical data from the foaling and foal it was hoped to define, or at least suggest, an aetiology for these haemorrhages in the neonatal foal.

CHAPTER 2.

MATERIALS AND METHODS.

2.1. INTRODUCTION.

Detailed ophthalmoscopic examinations were carried out on 169 neonatal Thoroughbred foals born on public and private stud farms in the United Kingdom (Newmarket, Suffolk; Arundel, West Sussex) and New Zealand (Matamata, Waikato). The examinations took place during the foaling seasons of the years 1982, 1983, 1985, 1986 and 1991. Foals were randomly selected from the population on each individual stud farm. All were examined within 96 hours of birth and thereafter as necessary. The protocol for the examinations was standardised and recorded on a custom designed form (Appendix 1, 2 and 3). A detailed ophthalmic examination was performed on each foal and results recorded using words, illustrations, and photography. Following this, a thorough clinical examination of the foal was undertaken and results recorded. Finally, details of breeding, pregnancy, foaling and post-partum behaviour were recorded.

2.2. OPHTHALMIC EXAMINATION.

The foal was restrained, usually in a standing position, for this part of the examination by one or two handlers. Those foals that were too young, or unable, to stand were examined in lateral recumbency. None of the foals received any chemical sedation, local anaesthetic techniques to facilitate examination, or mydriatics.

2.21 General External Inspection.

In a naturally or artificially lighted stable, the conformation and symmetry of the face, orbital regions and supraorbital fossae were assessed visually and, where necessary, by palpation. Evidence of periorbital trauma or abrasions, and signs of ocular pain such as photophobia, blepharospasm and enophthalmos, were evaluated. Particular note was paid to the type and amount of any ocular discharge. The position, size, and bilateral symmetry of both eyelids and globes were compared (figure 1).

2.22 Vision.

Vision was evaluated in each foal by close observation, by the author and experienced stud personnel, of the foal's behaviour at liberty in a foaling box and at exercise (Latimer and Wyman, 1985). The use of obstacle courses or mazes as suggested for use in the adult horse (Blogg, 1985; Hakanson and Meredith, 1987b; Lavach, 1990) was used on a number of occasions, but the results were compromised by the difficulty in leading neonatal foals. The cotton ball, or white gauze/sponge test (Lavach, 1990; Rebhun, 1991), was not used. The menace and pupillary light responses were also used to assess visual capability. Threatening movements of the hand towards the eye were used to test the menace response, taking care not to touch the eye or vibrissae, or to create sounds or air currents (Latimer and Wyman, 1985; Hakanson and Meredith, 1987b; Lavach, 1990; Rebhun, 1991) (figure 2). The pupillary light reflex was elicited by directing a bright, focal light beam from a pen torch or otoscope (Keeler, London) (figure 3).

2.23 Detailed External Ophthalmic Inspection.

2.23a Reflexes.

i) Menace.

The menace response was conducted as previously described, not only as a vision assessment but as a reflex itself (figure 2). It was recorded as absent or present. A positive response was usually indicated by withdrawal of the head and/or blinking. Care was required in interpretation of results, especially confusion with the normal head throwing reflex in the neonate (Adams and Mayhew, 1985).

From this stage onwards, the examination was conducted in a darkened stable.

ii) Pupillary Light Reflexes.

After noting the resting shape and degree of dilation of the pupil, both in daylight and a darkened stable (see chapter 12), a bright light from a pentorch or otoscope (figures 3 & 4) was directed onto the medial and lateral canthus of both left and right eyes, and the speed and magnitude of the pupillary light reflex recorded in the stimulated eye (direct), and the non-stimulated eye (indirect or consensual). Seven categories were developed to describe the type of responses seen:

1) PLR	Positive/Negative reflex.
2) PLR abnormality	Yes/No.

This category was used to describe a group of foals where the reflex was very sluggish, but nevertheless still positive (Blogg, 1985).

3) Consensual	Positive/Negative reflex.
4) Consensual abnormality	Yes/No.

A sluggish response as detailed in 2).

5) Direct	Positive/Negative reflex.
6) Direct abnormality	Yes/No. As above in 2) and 4).
7) Rapidity of response	a) Negative.
	b) Slow.
	c) Sluggish.
	d) Rapid.

In all category classifications an account was made of the degree of excitement shown by the foal. At the completion of the constriction by the pupillary light reflex, the degree of dilation of the pupil and its shape was recorded (see chapter 12).

iii) Blink and Photomotor Reflexes.

The effect on the eyelids of shining a bright focal light into the eye was recorded under the Photomotor reflex (figure 3). The response to gentle touching of the medial canthus of both eyes was recorded under the blink response (figure 5).

2.23b Orbit and Globe.

The results of general external inspection and further examination of the orbit using a pentorch or otoscope were recorded into four categories:

1) Size.

2) Bilateral symmetry.

3) Strabismus. Observing the horizontal axis of the pupil was the best way to assess the globe's position (Adams and Mayhew, 1984).

4) Other orbit abnormalities.

The anterior segment of the eye (eyelids, nictitans, conjunctiva, cornea, uvea, aqueous and lens) were examined using a bright focal light beam from an otoscope (figure 4). A complete examination was acheived by moving the light source to obtain illumination at various angles, and also separating the light source from the magnification lens.

2.23c Eyelids.

Both upper and lower eyelids of both eyes were examined.

i) Cilia.

The presence, size, and density of cilia (eyelashes) was recorded as present/absent, long/short, and dense/sparse respectively.

ii) Vibrissae.

The presence, size, and density of vibrissae (tactile hairs) was recorded as present/absent, long/short and 1-5/6-10 respectively.

iii) Abnormalities.

Any abnormality of the eyelids was noted. Particular attention was paid to the presence of entropion, epiphora, ocular discharge, eyelid defects or lacerations, blepharitis, contusions, abnormal cilia, and dermoids.

iv) Nictitans.

The nictitans or third eyelid was examined for presence, size, abnormality, and colouring. The latter was split up into whole coloured pink, pink with a black edge, and other colourations.

2.23d Conjunctivae.

The conjunctivae, both palpebral and bulbar, were assessed in left and right eyes. Any abnormalities were recorded. Of particular interest were subconjunctival haemorrhage, dermoids, and conjunctivitis.

2.23e Cornea.

The corneal size and shape were recorded as normal or abnormal. Abnormalities of the cornea were recorded. No attempt was made to measure the cornea accurately in each foal .

i) Opacity.

The presence of any corneal opacity was noted and its nature defined. Further investigation occasionally meant the use of a fluorescein dye test (figure 6) (Blogg, 1985; Hakanson and Meredith, 1987a; Rebhun, 1991) or conjunctival/corneal scrapings, smears, and bacteriology (Lavach, 1990) (figure 7).

ii) Pectinate Ligament/Scleral Shelf.

The presence of the insertions of the pectinate ligaments at the limbus was noted and assessment made of the areas of limbal circumference where it was most obvious. The position of any scleral shelf or overhang was also recorded.

2.23f Sclera.

Subconjunctival or conjunctival haemorrhage occurring over the sclera has previously, both in man and the horse, been referred to as scleral haemorrhages (Mahaffey and Rossdale, 1957; Rossdale, 1972a and b; Barnett, 1975). This is obviously a misnomer and recent literature clarifies this point (Munroe and Barnett, 1984; Latimer and Wyman, 1985; Lavach, 1990; Whitley, 1990). However, for the purpose of this thesis the original terminology will be used to simplify any discussion.

i) Scleral Haemorrhages.

The presence of scleral haemorrhages in either eye was noted. Their position, extent and colour was recorded, and further examinations made at later dates to assess the rate of resolution or onset of complications. The position of the haemorrhages (figure 8) was recorded as follows:

a) Dorsal.

b) Ventral.

c) Nasal.

d) Temporal.

e) Entire.

ii) Scleral Abnormalities.

The presence of scleral abnormalities other than haemorrhages were noted.

2.24 Detailed Internal Eye Inspection.

2.24a Iris.

i) Colour.

The colour of the iris was described as:

1) Dark Brown.

2) Grey Brown.

3) Grey.

4) Light Brown.

ii) Appearance.

The appearance of the iris was described as:

1) Mottled, where there was mottling or splotching at the periphery, often of a tan colour.

2) Homogenous, where there was a more even colouring.

3) Iridescent, where the mottling was grey rather than tan.

iii) Pupil.

As previously described, the size and shape of the pupils were recorded before and after examination of the pupillary light reflexes.

a) Size.

A percentage system was used to denote the degree of dilation of the pupils. Both the pupils were examined. Complete constriction of the pupil was equivalent to 0% and complete dilation (natural) to 100%.

b) Shape.

The pupillary shape was assessed pre- and post stimulation and placed in one of three categories:

1) Round.

2) Oval.

3) Elliptical.

Any difference between the bilateral symmetry of the pupillary size and shape was carefully noted (under Anisocoria) and investigated.

iv) Corpora Nigra (Granula iridica).

The presence of the corpora nigra was noted along the dorsal and ventral pupillary margins. Their relative size was assessed and placed in three categories: large, normal and small. Any abnormality or anomaly of the corpora nigra, including changes in shape, were recorded.

v) Persistent Pupillary Membrane.

The presence of any persistent pupillary membrane was noted. The size, extent, attachments, and position of any remnants was recorded.

vi) Abnormalities.

Any other abnormalities of the iris were recorded. Particular attention was paid to the presence of abnormal pigmentation, colobomata, uveal cysts, uveitis, hypopyon, hyphaema, and anterior or posterior synechiae.

2.24b Lens.

i) Introduction.

The lens was examined by focal light source (figures 3 & 4) and direct ophthalmoscopy. Close direct ophthalmoscopy was carried out using a hand held Practitioner ophthalmoscope (Keeler, London) (figure 9). Distant direct ophthalmoscopy (Crispin *et al*, 1990; Lavach, 1990) was occasionally used, but proved quite difficult to undertake in the neonatal foal (figure 10). A visible fundic reflection was produced by directing light from an ophthalmoscope into the pupil from a distance of 25-30cms. (Crispin *et al*, 1990). This retroillumination caused opacities in the optic media and lens to appear black. Opacities in the lens appear milky white or grey using the focal illumination. The ophthalmoscope was then moved closer to the eye (6-10cms.), and using the diopter wheel on the instrument, sharp focus on the dorsal corpora nigra was made. The exact diopter setting varied very slightly with the individual foal. By reducing the diopter strength, focusing was carried through the lens, into the vitreous, and finally onto the fundus (figure 11). Close direct ophthalmoscopy provided an image which was real, erect and magnified up to 15 times.

The location of any opacity within the lens was determined using two methods:

1) Sanson-Purkinje (Lavach, 1990; Rebhun, 1991).

A beam of light from the focal illumination directed into the eye produces a spot on the cornea and anterior/posterior lens capsule. The cornea and anterior lens spot move in the same direction as the light source; the posterior lens spot moves in the opposite direction (figure 12).

2) Parallax (Blogg, 1985; Lavach, 1990).

The axis of rotation of the equine eye is at the posterior pole of the lens. Distant direct ophthalmoscopy was used to view the eye. Any opacity anterior to the axis of rotation moved with the eye i.e. in the same direction as ocular movements. Those opacities close to the posterior pole move very little, or not at all. Opacities caudal to the axis i.e. vitreous, move opposite to the direction of eye movements (Hakanson and Meredith, 1987b) (figure 13).

A slit lamp biomicroscope would have greatly helped in differentiating opacities, especially posterior capsular cataracts and anterior vitreous abnormalities, but was not available (figure 14). However, the fact that vitreous opacities tend to oscillate after eye movement, whereas cataracts do not, helped in this study.

ii) General Lens Examination.

The lens was examined to evaluate its size, position, and any opacities (cataracts). The depth of the anterior chamber and the presence of iridodonesis were assessed. In those cases where there was an abnormality requiring further examination or photography, after completion of the full initial examination, a mydriatic (1% Tropicamide, Minims) was used to obtain full pupillary dilation. This was only required in very few cases, usually in older foals. When full dilation was achieved, lens zonules were seen at the lens equator.

iii) Sutures.

The presence, shape, and position of suture patterns (where lens fibres meet each other) in both lenses were noted. These were recorded, where applicable, by diagrams. Whether visible by focal illumination and/or direct ophthalmoscopy was noted.

iv) Hyaloid System.

Each individual eye was carefully examined for the presence, completeness, colour, and character of the hyaloid system. The information was recorded in words, diagrams and photographs. Particular attention was paid to the speed and form of withdrawal of the system. The hyaloid artery and posterior vascular rete or posterior pupillary membrane, along with the anterior vascular rete or anterior pupillary membrane, are responsible for the nutrition of the embryonic and foetal lens. These systems atrophy during late gestation and early neonatal life.

v) Other Abnormalities.

1) Cataracts.

A cataract is any opacity of the lens or lens capsule (Munroe and Barnett, 1984; Lavach, 1990; Whitley, 1990). The presence, anatomic position, degree of maturity, and possible cause of any opacity was recorded.

2) Other disorders.

Particular attention was paid to the presence of other congenital lens abnormalities, including lens dislocation, coloboma, aphakia and lenticonus/lentiglobus.

2.24c Vitreous.

The vitreous was examined by direct ophthalmoscopy (figures 9 & 10). The presence of the hyaloid system and its characteristics have already been discussed. Other abnormalities, especially opacities, were noted.

2.24d Fundus.

The fundus was examined using direct ophthalmoscopy (figure 9). This provided magnification, direct imaging, focusing for depth, and was easily carried out. The direct ophthalmoscope was held within 5cms. of the eye, and using diopter lenses focusing in from the vitreous to the fundus was achieved. A sharp image was usually possible with a diopter range of -1 to -3 (figure 11). Each fundus was examined.

The examination took place in a sequential order:

i) Optic disc.

ii) Retinal vessels.

iii) Tapetal fundus.

iv) Non-tapetal fundus.

v) Presence of retinal haemorrhages.

i) Optic Disc.

The examination began as soon as the optic disc was located and focused on.

a) Colour.

The colour was categorised as :

1) Pale Pink.

2) Pink.

3) Red-Pink.

4) Red.

5) Orange.

b) Shape.

The shape of the optic disc was recorded as:

1) Normal.

2) Abnormal.

3) Round.

4) Large.

5) Small.

6) Oval/Flat-Oval.

7) Triangular.

8 Ventral Notch or Fissure.

9) Dorsal Bulge or Extension.

c) Character

The character was recorded as:

1) Normal.

2) Homogenous.

3) Light centre and border.

4) Light centre.

5) Light border.

6) Midventral white rim.

7) Increased myelination.

8) Ragged edge.

9) Indistinct edge.

10) Decreased pigment.

The description of the individual disc consisted of a combination of b) and c).

d) Location.

The position of the optic disc within the fundus was recorded.

e) Appearance.

The presence/absence of the following 3 categories was recorded:

1) Retinal Haemorrhages involving disc .

2) Papilloedema.

3) Unfocusable optic disc.

ii) Retinal Vessels.

The equine fundus is paurangiotic, i.e. only the central fundus has retinal vessels. Examination of the retinal vessels was begun immediately after the optic disc.

1) Normal vessel pattern.

2) Increased tortuosity of Vessels.

Position of increased tortuosity:

a. Intra-Disc.

b. Extra-Disc.

3) Increased size of vessels - diameter and/or length.

4) Decreased size of vessels - diameter and/or length.

5) Increased numbers of vessels.

6) Decreased numbers of vessels.

7) Haemorrhage.

iii)Tapetal Fundus.

The presence and size of the tapetal fundus was confirmed. The colouration of the tapetal fundus varies considerably (Munroe and Barnett, 1984; Latimer and Wyman, 1985; Lavach, 1990; Rebhun, 1991). The tapetal colour was recorded under one or more of the following categories:

a) Colour:

1) Yellow.

2) Yellow/Orange. Green peripheral border.

3) Nasal Yellow. Temporal Green.

4) Green with Yellow periphery.

5) Yellow-Green.

6) Green.

7) Bluish.

8) Mottling

a) dorsal.

b) ventral.

c) none.

9) Albinism.

b) Stars of Winslow.

The presence of the Stars of Winslow (penetration of tapetum by small choroidal vessels) (Munroe and Barnett, 1984; Lavach, 1990) was recorded.

c) Choroidal Vessels.

Visualisation of underlying choroidal vasculature in areas of the tapetal fundus with a relative lack of overlying tapetum or retinal pigment has been recorded (Latimer *et al*, 1983; Munroe and Barnett, 1984; Latimer and Wyman, 1985; Hakanson and Meredith, 1987b; Lavach, 1990; Rebhun, 1991). These were recorded in this survey as:

1) Present/Absent.

2) Red-Pink/Bluish.

3) Position:

a) Dorsal to disc.

b) Widespread.

iv) Non-Tapetal Fundus.

The examination of the non-tapetal fundus (tapetum nigrum) was divided into 2 parts:

1. Border.

The junction between tapetal and non tapetal fundi.

a) Straight.

b) Ragged.

c) Presence of atypical coloboma near border.

2. Main Area:

a) Colour:

i) Dark Brown.

ii) Light Brown/Grey.

iii) Black.

iv) Other.

b) Appearance:

i) Atypical Coloboma.

ii) Dorsal Disc Depigmentation.

iii) Light Grey Streaks.

iv) Others.

v) Retinal Haemorrhages.

The presence of retinal haemorrhages was recorded in each eye. Their number was recorded as:

a) None.

b) 1 - 5.

c) 6 - 10.

d) > 10.

The type of haemorrhage was noted as:

a) Small Punctate (petechiae).

b) Splash-Like (ecchymosis) - small.

- large.

Distribution of haemorrhages over the tapetal fundus (figure 15) was documented as:

a) Discrete (dorsal, nasal,or temporal to optic disc).

b) Widespread.

c) Optic Disc only.

An attempt was made to separate the haemorrhages into 2 stages of development based on colour, shape and general appearance:

a) Acute.

b) Resolving.

All foals with retinal haemorrhages were re-examined at later stages to document the progress and resolution of the haemorrhages and any effect on the foal.

2.3. NEONATAL FOAL EXAMINATION.

Each neonatal foal received a full physical examination and assessment of their behaviour, following the ophthalmic examination. The sequence and extent of this standard neonatal examination has been described (Rossdale and Ricketts, 1980; Adams and Mayhew, 1985; Varner and Vaala, 1986; Koterba, 1990a; Stoneham, 1992).

The size of the foal in kilograms was recorded into 4 groups:

a) Small - less than 45kgs.

b) Normal - 45-50kgs.

c) Large - 51-56kgs.

d) Very Large - 57kgs. and over.

The majority of foals were weighed, otherwise two experienced stud personnel and the author estimated the weight into the four categories.

The sex and colour of the foal were checked and recorded. Careful inspection of the coat was necessary to accurately describe the foal colour, especially in black, grey and brown foals.

The time taken for the foal to stand unassisted and suck the mare was recorded as:

Time to stand:

a) <1 hour.

b) 1-3 hours.

c) >3 hours.

Time to suck:

a) <2 hours.

b) 2-4 hours.

c) >4 hours.

The order and extent of the clinical examination were as follows:

a) General behaviour.

b) Respiratory rate and character (20 - 40 B.P.M.).

c) Temperature (37.2° - 38.2°C).

d) Degree of hydration based on skin turgor.

e) Oral mucous membrane colour.

f) Capillary refill time.

g) Examination of mouth for cleft palate.

h) Presence and character of nasal discharge.

i) Chest auscultation - respiratory sounds.

- heart rate, rhythm, murmur.

j) Palpation of umbilical and inguinal regions.

k) Palpation of legs, head, and body (especially the chest wall).

l) Check for passage of meconium, faeces and urine.

m) Palpation of abdomen.

n) Walk foal around box.

Where abnormalities were detected the foal, and on occasions the mare and placenta, were further examined, often in some detail, to ascertain an exact diagnosis and appropriate treatment. Regular examinations were then continued as necessary.

A large percentage of the foals in the survey, including all the U.K. foals, had blood taken between 12-48 hours after birth for routine haematological analysis and biochemical profiles, including levels of globulin and/or IgG.

The findings of the neonatal examinations were categorised into normal and abnormal, the latter being further divided into the basic groups of equine neonatal disease as defined by Rossdale and Ricketts (1980), and subsequently by Koterba, Drummond and Kosch (1990).

2.4 GESTATIONAL AND PARTURITION HISTORY.

Details of the foaling and previous pregnancy were obtained from the stud farm manager and/or groom who attended that mare on each stud farm. In some cases additional information was given by the veterinary surgeon servicing the stud or obtained from records. Many of the studs kept detailed records, especially of the preparturient, parturient, and immediately post parturient periods. Although the criteria for foaling behaviour and parturient difficulty (figure 16) were subjective judgements, they were made by experienced people, were fairly consistent within an establishment, and were based on well known information (Rossdale and Ricketts, 1980). Delivery was graded as:

1) Easy, normal and unassisted with second stage 10 - 30 minutes.

2) Rapid, normal and unassisted with second stage less than 10 minutes.

3) Assisted, usually by stud groom, due to foetal oversize. Additional traction applied to the foal's forelimbs.

4) Miscellaneous types such as unattended foalings, prolonged first stage, premature presentation of the allanto-chorion, mare standing for delivery, placentitis, early cord rupture, and obturator paralysis.

5) Difficult, where major manipulations and assistance were required by the groom or veterinary surgeon before the foal could be successfully delivered.

The details regarding pregnancy were split into normal and abnormal categories. The latter was further subdivided into sections including prolonged or short gestational period based on covering (conception) dates, late gestation colic, preparturient mammary gland milk loss, vulval and cervical discharge, and abnormalities of the mare such as laminitis or limb oedema.

2.5 STATISTICS.

The data from each foal was recorded on individual forms in words and diagrams (Appendix 1). This data was transformed onto a Database IV (IBM Corporation) programme. This data was then transferred via an Ascii file onto the University of Glasgow main frame computer where statistical analysis was carried out using a Minitab Release 8 (IBM) programme.

Two way relationships between variables was investigated using the Chisquare Test of Independence. This test basically examines the differences existing between the observed values, and those expected if the two variables being tested were independent. Where large differences existed, the hypothesis that the variables were independent was rejected. The test was deemed inaccurate where expected values less than 2 existed, leading to the Chisquare approximation being invalidated. In such cases other statistical methods were used. Either Fishers Exact Test was performed or categories were grouped to give expected values greater than or equal to 2. In both tests, because of the large number of relationships being investigated, a significance level of 1% ($p < 0.01$) was used to avoid spurious results. In order to analyse three-way relationships between variables, a log-linear model was fitted in BMDF using program 4F. This model represents the natural logarithm of the expected cell frequency as a linear combination of main effects and interactions. Of real interest to this project were the inter-relationships existing between variables, and the significance of these were tested by deleting a particular effect from the model. A 1% significance level was used.

2.6 PHOTOGRAPHY.

Fundic and some external eye photography was undertaken using a Kowa RC2 fundus camera (figure 17). Additional external eye photographs were taken using a Yashika FX3 single lens reflex camera (figure 18), fitted with automatic connecting tubes, and using a flash gun. All photography was recorded onto Fujichrome 100 ASA slide film, and selection of suitable examples made before processing into prints.

The quality of the photographs in this thesis was affected by certain difficulties met in this survey. The problems of restraining the healthy neonatal foal, and its head in particular, are considerable, especially where chemical means are unavailable. The additional factor of causing minimal disturbance to foal and associated humans was always uppermost in the author's mind, particularly, for what was considered nonessential work. Although the pupils were often large and relatively unresponsive to light, constriction on use of the fundic camera did occur, compromising the field of view. Owners were not prepared to allow the use of mydriatics in normal foals.

The colour rendition of the figures in this thesis may not completely mirror those seen and recorded by the author at the examination, due to the effects of film colour sensitivity, exposure factors, printing, and colour perception.

CHAPTER 3.

GESTATIONAL AND PARTURITIONAL DATA OF THE MARE.

3.1 INTRODUCTION AND REVIEW OF LITERATURE.

This data was recorded after examination of the foal, to build up a complete picture of its early life in utero and obtain detailed information on the crucial event of parturition.

3.11 Parent Identification.

Both the name and colour of the dam and sire of the foal were recorded. The identification of Thoroughbred foals in the U.K. and New Zealand is undertaken by Weatherbys who control the General Stud Book. All new foals are identified by their own markings, their breeding, and by genetic blood typing. It is therefore possible to trace any foal throughout its life by recording its markings, breeding and year of birth (regardless of its subsequent name). This became very important in those foals in which long term followup was attempted, since many foals leave their birthplace to return to other studs and premises relatively early in their lives. Further dispersal occurs at foal and yearling sales.

The colour of the parents, besides helping in identification was also recorded to allow the effect of parent colour on progeny coat colour to be examined.

3.12 Gestational History.

Gestational history provides, along with the events of parturition, the only "case history" available for neonatal disease (Young, 1992b). The foetus and placenta are hidden from direct view throughout pregnancy, but may nevertheless be affected by abnormalities, or disease processes, which manifest themselves as neonatal problems, some of them involving the eye. Conditions such as purulent vaginal discharge, excessive medication administration to the mare, and significant colostrum leakage pre-partum have been associated with the production of high-risk neonatal foals (Koterba, 1990b). Until recently, foetal assessment in the pregnant mare was restricted to rectal palpation and a good clinical history (Adams-Brendemuehl, 1990). However, during the period of this project, a number of techniques came into use to help monitor foetal placental health and foetal "readiness for birth", and these were used where indicated. These included maternal plasma progesterone assay (Leadon, Jeffcott and Rossdale, 1984; Santschi, Le Blanc and Rossdale, 1988; Young, 1992a); maternal oestrone sulphate concentrations (Pashen, 1984); foetal electrocardiography (Colles and Parkes, 1978); abdominal ultrasonography (Adams-Brendemuehl and Pipers, 1987; McGladdery, 1992); and mammary gland/teat development and secretion analysis (Ousey, Dudan and Rossdale, 1984; Cash, Ousey and Rossdale, 1985).

3.13 Parity.

As part of the gestational history, the separation of mares into primiparous and multiparous groups was undertaken. Some gestational and parturient conditions appear more commonly in these groups and may have an adverse effect on the neonatal foal and the appearance of its eyes (Rossdale and Ricketts, 1980; Munroe, 1988; Le Blanc, 1991; Munroe, 1992).

3.14 Foaling Behaviour.

Just as abnormal gestational events can affect the neonatal foal, so the process of parturition, whether normal or abnormal, may also alter neonatal behaviour and well-being (Rossdale and Ricketts, 1980; Koterba, 1990b). Conditions such as premature parturition, dystocia, Caesarean section, and premature placental separation have all been implicated in the high-risk newborn foal (Koterba, 1990b).

Detailed descriptions of parturition in the mare are readily found (Arthur, 1975; Ginther, 1979; Rossdale and Ricketts, 1980; Hillman, 1983; Crowell-Davis and Houpt, 1986; Roberts, 1986; Allen, 1988; Le Blanc, 1991). Parturition is usually divided into three stages. Stages one, two and three culminate in rupture of the allantochorionic membrane, delivery of the foal, and expulsion of the foetal placental membranes, respectively (Ginther, 1979). The length of first stage labour is variable from minutes to several hours (Jeffcott, 1972; Ginther, 1979; Rossdale and Ricketts, 1980; Crowell-Davis and Houpt, 1986), but second stage labour is more brief and constant in length. Between 10-20 minutes (range 5-60 minutes) is quoted in the literature (Ginther, 1979; Rossdale and Ricketts, 1980; Crowell-Davis and Houpt, 1986).

The incidence of dystocia in mares is reported to be low, 4% among Thoroughbreds (Rossdale and Ricketts, 1980), and can be broadly separated into two categories. Maternal causes, which, according to Vandeplassche *et al* (1972), constitute only about 5% of dystocias in the equine, include uterine inertia, absence of voluntary abdominal straining, and uterine torsion. Foetal causes include malpostures/malpositions/malpresentations, congenital deformities, and also foetal absolute or relative oversize (Arthur, 1975; Rossdale and Ricketts, 1980). Other abnormal conditions associated with birth include internal and external reproductive tract haemorrhage, hypocalcaemia, uterine rupture, uterine prolapse, gastro-intestinal tract damage, perineal lacerations, foaling whilst standing, and pelvic fractures/obturator paralysis (Rossdale and Ricketts, 1980; Hillman, 1983; Munroe, 1992; Simpson, 1992).

3.15 Foaling Time.

Mares foal predominantly at night (Rossdale and Short, 1967; Jeffcott, 1972; Bain and Howey, 1975; Rossdale and Ricketts, 1980; Campitelli, Carenzi and Verga, 1982; Rao and Swamy, 1990). In a survey conducted with Thoroughbred mares, 86% foaled between 19.00 and 07.00 hours with a maximal incidence between 22.00 and 23.00 hours (Rossdale and Short, 1967). Many factors, including sex and genotype of the foetus, heritability, seasonal influence, and other specific environmental causes, are known to influence gestation length in mares (Rossdale and Short, 1967). Mares prefer solitude and quiet at parturition and, given the opportunity, will go off by themselves to foal. Maternal influence on the time of parturition has been demonstrated by studies which suggest it occurs when stable activities are at a minimum. The mechanism whereby this happens is not yet understood, but the pituitary gland and the neurohormone oxytocin have been implicated (Le Blanc, 1991).

Foaling occurs in the mare not influenced by human management, throughout the year but with a strong peak in April, May and June in the northern hemisphere (Feist and McCullough, 1975; Crowell-Davis and Houpt, 1986). Thoroughbred mares are, however, managed to produce early conception and parturition (January - March), thereby increasing the actual age of the progeny on their first birthday (following January 1st.) (Rossdale and Ricketts, 1980; Rao and Swamy, 1990).

3.2 RESULTS.

3.21 Parent Identification.

The colour of each parent is shown in Table 3.1

	Mare	% of Total	Stallion	% of Total
Bay	98	58	96	56
Chestnut	37	22	43	25
Grey	9	5	12	7
Brown	5		3	
Bay-Brown	7	4	2	
Black	0		3	
Unknown/ Unrecorded	13		10	
Total	169		169	

There was a strong correlation between Mare and Stallion coat colour distribution and between progeny and parent coat colour (figure 19). Over 60% (of those recorded) of both mares and stallions had a bay coat colour and approximately 25% were chestnut. All other coat colours occured as single figure percentages.

3.22 Gestational History.

The incidence of abnormalities of pregnancy are shown in Table 3.2

Abnormal	48	28%
Normal	121	72%

The abnormalities were further divided into specific categories.

Gestational Length.

41 of the 48 abnormal pregnancies were described as variations in the length of gestation and these are detailed in Table 3.3

days	Overdue	Premature
> 5	8	6
>10	13	6
>20	6	2
Total	27	14

27 pregnancies (16%) were described as overdue and 14 (8%) premature based on a proposed parturition date of 336 days from the date of the last covering. In total, 24% of all mare gestational lengths were outside the 336 +/-5 day period.

Pre-Partum Lactation.

In total 5 mares had premature loss of colostrum, ranging in length from 1-21 days pre-partum. 4 of these pregnancies were overdue (2 >10, 2 >20 days). All of the five foals produced were supplemented with additional colostrum within 24 hours of birth.

Pre-Partum Colic.

2 mares had abdominal pain of varying length and degree in late pregnancy, on which a specific diagnosis was not made. Both mares responded to mild analgesics and recovered without additional treatment. 1 mare was very premature in foaling (28 days pre-term), but produced a normal foal.

Cervical/Vaginal Discharges.

2 mares had discharges from the vulva in late pregnancy, one of which was confirmed to be coming through the cervix. This mare had a placentitis, confirmed at foaling, and produced an abnormal foal (figure 20). The other foal and placenta were normal at birth.

Orthopaedic Problems.

2 mares had problems involving their hindlimbs during a considerable portion of the last trimester of pregnancy. Both produced rather weak, dysmature foals. Both mares were lame and in considerable pain for a long period, and required extensive use of analgesics.

Miscellaneous Problems.

4 mares had problems that did not fit into any other category. 1 mare sustained a severe vulval kick from another mare, 2 mares failed to increase body condition and weight and were considered underweight, and 1 mare had an idiopathic thrombocytopaenia in the last trimester of pregnancy which responded to corticosteroid therapy. The 2 underweight mares produced poorly developed, weak foals.

Statistically there was no relationship between an abnormal gestational history and mare parity, foal size or sex. Normal pregnancies were overrepresented in foaling category 1, and abnormal pregnancies in categories 3 and 4, leading to there being, in general, a statistically significant correlation between foaling category and gestational history. Overall, the relationship between gestational history and foal behaviour, including time to stand/suck, was only marginally significant but, if the abnormal gestational lengths were removed, the statistical relationship was more obvious.

3.23 Parity.

The parity of the foaling mares is recorded in Table 3.4

Uniparous	27	16%
Multiparous	142	84%

As already stated, there appears to be no relationship, in this study, between maternal parity and the incidence of any abnormality of pregnancy. Similarly, foal behaviour and parity are not correlated. Maternal parity and foal size appear to be statistically correlated, with an overall tendency for multiparous mares to produce larger foals (all size 4 foals were from multiparous mares), and uniparous small foals (size 1).

3.24 Foaling Behaviour.

The behaviour of the mares in this survey was divided into 5 categories and is shown in Table 3.5

Category	No. of Foals	
1	119	70%
2	1	
3	28	16%
4	20	12%
5	3	2%

Foals number 72 and 115 had more than one category. 72 was categories 1 and 4, and 115 was categories 3 and 4.

Categories 4 and 5 were further subdivided into separate groups as shown in Table 3.6

Category 4: Miscellaneous.

Unattended foalings	4	(70, 90, 114, 119)
Prolonged first stage	2	(99, 123)
Premature Presentation of Allantochorion	2	(92, 73)
Standing Delivery	1	(109)
Placentitis (figure 20)	1	(69)
Early Umbilical Cord Rupture	3	(72, 74, 165)

Category 4: Miscellaneous.

Obturator Paralysis	1	(112)
Premature Separation of Allantochorion	2	(91, 102)
Malposition in early second stage corrected by rolling mare	2	(108, 132)
Vulva Stitched	1	(110)
Retained Placenta	1	(115)

Category 5: Difficult Foalings.

Leg back malposture, rapid manipulation	2	(71, 95)
Bilateral carpal flexure and head back malposture, prolonged manipulation	1	(113)

120 mares (70%) had a normal foaling, with 28 (16%) requiring manual assistance to foal due to foetal oversize. Only 3 mares (2%) had an overt dystocia.

Foaling categories were strongly correlated with the parity of the mare. Category 3 and , to a lesser extent, category 5, were very much more common in uniparous mares. The relationship of foaling category with gestational history has already been stated and that with foal sex, size and behaviour will be discussed in the next chapter, although interestingly the latter is significantly correlated.

3.25 Foaling Time.

The numbers of mares foaling at each time on the 24 hour clock are shown in Table 3.7.

Foaling Time.

00.05	2	**16.00**	1
00.10	1	**16.30**	1
00.30	5	**17.30**	1
00.45	2	**18.00**	1
01.00	7	**18.15**	1
01.15	2	**19.00**	7
01.30	6	**19.20**	1
01.50	1	**19.30**	1
02.00	3	**19.50**	1
02.30	4	**20.00**	7
03.00	6	**20.30**	5
03.30	4	**20.40**	1
03.45	1	**21.00**	16
03.55	1	**21.25**	1
04.00	8	**21.30**	3
05.00	3	**21.45**	1
05.30	2	**22.00**	11
06.00	2	**22.17**	1
06.30	2	**22.30**	5

Foaling Time.

07.30	2	**22.40**	1
08.00	1	**22.45**	3
09.15	1	**23.00**	11
09.45	1	**23.30**	5
10.00	1	**23.45**	3
10.30	2	**23.50**	2
12.00	3	**23.55**	1
13.00	1	**Unknown**	2
14.00	1	**Total**	169

These results are plotted against a 24 hour baseline in figure 21.

The mean of the foaling times is 23.55 with a standard deviation of ± 4.09 hours. Both figure 21 and the mean confirm that the majority of mares foal between the hours of 20.00 (8 pm) and 04.00 (4 am). The large numbers of foals that appear to be born on the hour i.e. 23.00 etc. is a function of the rounding-up often practised by stud personnel when recording times on stud records.

The time of year in which foaling occurred is plotted in Figure 22 for the U.K. and Figure 23 for New Zealand. The actual foaling dates are batched up into weeks, each month of the year being ascribed 4 weeks.

Table 3.8 shows the number of foals examined on a yearly basis.

1982	4
1983	51
1985	52
1986	19
1991	43

3.3 DISCUSSION.

3.31 Parent Colour.

The strong statistical relationship between mare, stallion and foal coat colour suggests a high genetic heritability of coat colour in the Thoroughbred. Because of this, those coat colours that occur commonly in this breed (Bay and Chestnut) continue from generation to generation. Interestingly, these results also confirm the decline in recent decades, in the general Thoroughbred population, of darker coloured horses, especially blacks, and also greys.

3.32 Gestational History.

The incidence of abnormal gestational history in this survey initially appears quite high at 28%. However, on subdivision into specific problems it becomes apparent that 85% of these abnormalities are related to variations in gestational length, which can be highly variable from mare to mare (Le Blanc, 1991).

Gestational Length.

On Thoroughbred stud farms it is usual to calculate the expected date of parturition as 11 calendar months from the last covering or service, i.e. a gestational length of 333-336 days (Rossdale and Ricketts, 1980). Statistical surveys confirm this by giving the mean gestational length in Thoroughbreds as 338-340 days, with a range of 310-374 days (Rossdale, 1967; Campitelli *et al*, 1982; Crowell-Davis and Houpt, 1986; Roberts, 1986; Singhvi, 1989). In other breeds means of 322-345 days have been reported (Jeffcott, 1972; Ginther, 1979; Rossdale and Ricketts, 1980). Gestational length is therefore variable, and sex of the foal, month of conception, and the dam have significant effects on pregnancy duration. No significant difference is attributable to the sire of the foal, sire of the dam, age of the sire or dam, or year (Howell and Rollins, 1951; Jeffcott, 1972; Rossdale and Ricketts, 1980; Campitelli *et al*, 1982; Crowell-Davis and Houpt, 1986; Singhvi, 1989). There is genetic variation in gestational length independent of environmental factors (Rollins and Howell, 1951). The foetus determines the duration of its own intrauterine life and its phenotype has an important bearing, as evidenced by work using crosses between horses and donkeys (Rossdale and Ricketts, 1980; Singhvi, 1989).

From the extensive work carried out on this subject it can be seen that there is a high degree of variability in gestational length, and choosing a band of "normal" lengths outside which the pregnancy is termed abnormal is open to varied interpretations. It would certainly explain why such a large percentage of mares (24%) were outside the 336 +/-5day gestational length used in this survey. Further work with foals (Rossdale and Ricketts, 1980; Koterba, 1990c) has suggested that foals born younger than 320 days gestation might be described as premature, as long as they display immature physical characteristics. Using this definition only 2 foals in the survey would be premature on dates but, in fact, both were physically and haematologically considered mature.

Prolonged gestation has also been associated with high risk neonatal foals (Koterba, 1990a). Some of these pregnancies are related to foetal gonadal and/or placental dysfunction and foetal mummification, especially in twin pregnancies (Vandeplassche, 1988; Munroe, 1992). Vandeplassche (1988) has stated that pregnancies, in the absence of any abnormal clinical signs, of up to 365 days can be considered within normal variation. These pregnancies, and those 1% that continue for longer than 370 days, often have a spontaneous parturition producing a foal of normal size and maturity. Some may be related to delayed conceptual development (embryonic diapause). This survey confirmed this previously stated view, with all 27 foals born overdue, being normal at birth and often of average birth weight. The large numbers with prolonged gestation in this survey may have been related to the fact that the majority were born in the February - April period (March - May matings), in which Rossdale and Short (1967) have already stated that the pregnancies are on average 10 days longer than those produced by matings at other times of the year. The effect of the sex of the foal on gestational length was not confirmed by this survey, but individual mares with consistently "abnormal gestational lengths" were not uncommon.

In conclusion, abnormalities of pregnancy in this survey that involved gestational length rarely had any effect on the foal produced, and only marginally on degree of parturition difficulty. This leads one to the conclusion that the majority of gestational length abnormalities in this survey were within the normal biological variation seen in the Thoroughbred mare.

Pre-Partum Lactation.

Premature lactation has been associated with twin pregnancies, placentitis and placental separation (Le Blanc, 1990; Young, 1992a). It may therefore indicate abnormalities of the foetoplacental unit, possible neonatal abnormalities, and lack of foetal "readiness for birth" (Rossdale and Silver, 1982; Young, 1992a). It is also seen as a normal physiological variation in some mares (Rossdale and Ricketts, 1980). The mechanisms whereby mammary development and secretion are co-ordinated with the foetoplacental unit and its maturation are not well understood, but they certainly exist. The monitoring of mammary development and secretion, including biochemical analysis, is a well recognised technique as part of the monitoring of "foetal readiness for birth" and mare/foetus health (Leadon, Jeffcott and Rossdale, 1984; Ousey, Dudan and Rossdale, 1984; Le Blanc, 1990; Young, 1992a).

All 5 mares with premature lactation were subjected to serial examinations of mammary secretions, foetal ECG, blood endocrine levels, and abdominal ultrasonography. None of them appeared to have any detectable abnormality of the foetus or placenta, and all foaled normally producing normal foals. These mares might, therefore, be reasonably placed in the normal variation category.

Mares that prematurely lactate for more than 24 hours before foaling, tend to have lower colostral IgG concentrations than those that lactate normally (Le Blanc and Tran, 1987). Hence all 5 foals so affected in this survey received colostral supplementation within the first 6 hours of birth. Their IgG levels, when checked at 18-24 hours post partum, were within normal limits.

Pre-Partum Colic.

Many pre-partum maternal abnormalities present with colic, usually of uterine origin (Vandeplassche, 1988; Le Blanc, 1991; Munroe, 1992). Although in the 2 mares presenting with abdominal pain in this survey it was not possible to make a specific diagnosis, conditions known to cause such signs include abortion/premature parturition, foetal hypermobility, uterine dorsoretroflexion, uterine torsion and gastro-intestinal problems (Vandeplassche, 1988; Le Blanc, 1991; Munroe, 1992). Both foals produced were normal.

Cervical/Vaginal Discharges.

Discharges from the vulva, vagina and/or cervix are not uncommon in late gestation (Munroe, 1992). They can indicate impending abortion/premature parturition, but in many cases the pregnancy is carried to term and a normal foal delivered. One of the 2 cases seen in this survey behaved in such a way. Some cases are related to a localised vaginitis/cervicitis, early liquifaction of the cervical plug, or may reflect a localised placentitis (cervical star). The latter was confirmed at parturition in the other case seen in this survey (figure 20), and lead to a dysmature foal (figure 25). This had been predicted, based on a pre-partum foetoplacental health assessment.

Orthopaedic Problems.

Late pregnancy mares can develop a variety of orthopaedic problems, particularly of the hindlimbs, due to excessive body weight, abnormal levels of exercise, overuse injuries in older mares, or poor circulation/lymphatic drainage (Munroe, 1992). Both cases in this survey were good examples of these types of conditions. One sustained an injury of the medial collateral ligament of the femoro-tibial joint, the other developed serious peripheral hind limb oedema and lymphangitis due to overuse injuries of the hindlimb suspensory apparatus and fetlock joints. Both required continual medication, were in considerable pain despite this, lost a significant amount of body weight and, as was predicted, produced weak, dysmature foals (Koterba, 1990c).

In conclusion, therefore, many of the mares that were classified in this survey as having an abnormal gestational history and the potential to produce an abnormal foal, did in fact appear to fit into the grey area of variations within biological normality, and gave birth to clinically normal foals. Nevertheless, abnormal pregnancies, as defined in this survey, did appear to have an effect on the foaling category and, if the biological variants were removed, on the incidence of abnormal foal behaviour. Their relationship to abnormalities of the eye will be discussed in later chapters.

3.33 Maternal Parity.

The number of uniparous mares in this survey (16%) is considered normal for the general population of foaling Thoroughbred mares, bearing in mind that the numbers of barren, foaling and maiden mares visiting a particular stallion varies each year. This variation depends on such factors as stallion fee, availability, suitability, fashion, and success rate of progeny. Up to 25% of a stallion's mares may be maiden foalers.

The importance of parity as part of the gestational history, is highlighted by some of the results of this survey. Both neonatal foal size and type of foaling were statistically related to parity. Uniparous mares are more likely to produce smaller foals (size 1), although there is no relationship of this smaller size with foal abnormality in this group. Campitelli *et al* (1982) stated that middle-aged mares (6-11 years), most of which would be multiparous, produced heavier foals. This is confirmed in this survey where multiparous mares produced all the size 4 foals. Interestingly, despite the smaller size of the foal generally produced, there is a strong correlation of uniparity with foaling category 3 (foetal oversize) and the small numbers in category 5 (major manipulations). Simpson (1992) described the condition of relative foetal oversize in uniparous mares and thought it resulted mainly from inadequate pelvic ligament relaxation leading to lack of room for passage of the foal. Vandeplassche (1988) noted that the incidence of dystocia was increased, and Crowell-Davis and Houpt (1986) that parturition was longer, in uniparous mares. Drost and Asbury (1981) stated that primiparous mares may have tight vestibulovaginal sphincters that delay parturition and predispose to lacerations and rectovaginal tears. Finally, this survey suggested that there was no relationship between maternal parity and pregnancy abnormality, although Ousey (pers. comm.) has suggested that premature lactation is more common in uniparous mares.

3.34 Foaling Behaviour.

The foaling behaviour in this survey was divided into 5 categories. The first two consisted of normal parturition where no human assistance was given. In the fourth category, which consisted of a mixture of miscellaneous abnormalities at foaling, assistance was only given during premature presentation or separation of the allantochorion, and standing delivery. The assistance given was similar to category 3 (foetal oversize), where gentle traction was applied by one or two experienced stud personnel to the foal's forelimbs to facilitate passage of the head and thorax through the pelvic canal and vulva. Full return of placental blood was allowed before removing the rest of the foal. Only 3 foals had major obstetric manipulations before vaginal delivery was effected. 2 of the foals were normal, the other had a "contracted foal syndrome" and was destroyed (see chapter 4). Only one of the mares had any post partum problems, which was an easily removed retained placenta. The 2% incidence of these dystocias was lower than the expected 4% (Rossdale and Ricketts, 1980), and all were of foetal origin. However, the incidence of foetal oversize (Hillman, 1983; Vandeplassche, 1988; Simpson, 1992) was high at 16% and, as has already been noted, has a relationship to the parity of the mare. Some of the relative oversize in uniparous mares may be caused by the regular use of 3 and 4 year old maiden mares for breeding, at a time when they may not be fully physically mature.

In multiparous mares relative or absolute foetal oversize may be due to incompatability of parents, excessive gestational nutrition leading to large foetal birth weight, and prolonged gestation.

Further examination of the miscellaneous group reveals that 2 of the unattended foalings, and the prolonged first-stage, produced normal foals and could easily be placed in the normal foaling category. First-stage labour in the mare is very variable and can last from minutes to hours, before continuing to second-stage or ceasing, to resume hours or days later (Rossdale, 1967; Jeffcott, 1972; Rossdale and Ricketts, 1980). Some mares, as seen in this survey, may stand for part or the whole of the second stage. In many cases this appears not to affect the progress of parturition but, if delivery of the foal occurs in this position, premature umbilical cord rupture can occur. Support of the foal, as in the case in this survey, stopped this from happening and a normal foal was produced. Premature umbilical cord rupture was seen in 3 mares for other reasons and two of the foals produced were abnormal. This confirms the work carried out by Rossdale (Rossdale and Ricketts, 1980) which suggests that early rupture or severance of the umbilical cord can deprive the foal of up to 1 litre of placental blood and predispose it to abnormality (Koterba, 1990a). Premature separation or presentation of the allantochorion was seen in 4 foalings and lead to the immediate delivery of the foal with human assistance. Le Blanc (1991) and Simpson (1992) have stated that this condition constitutes an emergency, since it leads to impeding of foetal passage and foetal death in utero due to hypoxia. Koterba (1990a) states that it is a common cause of high-risk neonatal foals due to foaling stress, hypoxia and septicaemia secondary to placentitis. The latter was seen in the one foal that was subsequently abnormal, of the four that were born in this way. The other foal born to a mare with placentitis was also abnormal and dysmature, as was the foal born with the vulva still caslicked. All the other miscellaneous foalings produced normal foals.

In conclusion, foaling category was statistically related to the parity of the mare, the gestational history of the mare and, as will be discussed in the next chapter, with foal behaviour and size. It is this latter relationship that is of most interest when looking at the effect of foaling on the eye of the neonate.

3.35 Foaling Time.

The pattern of foaling times in this survey very closely resembles that for Thoroughbred mares already in the literature (Rossdale and Short, 1967; Ginther, 1979; Rossdale and Ricketts, 1980). 78% of all foalings occurred within the standard deviation of the mean i.e. 20.00 - 04.00 which is very similar to the findings of Rossdale and Short (1967), Bain and Howey (1975) and Rao and Swamy (1990). The peak period was just before midnight. This is at the quietest time of the night, following the staff of the stud leaving some 5 - 6 hours earlier. An interesting theory for this time period involves the concept that birth around midnight in the wild would allow enough time for birth, standing, sucking and development of the ability to move rapidly, before daybreak and the arrival of predators (Bain and Howey, 1975). There was no significant difference between U.K. and New Zealand foaling times, although there were slightly more foals born in the daylight hours in the latter. This may be due to different management patterns.

The distribution of the foaling in U.K. foals in this survey is heavily concentrated in February, March and April, and in New Zealand in September and October. Although this distribution of foaling probably reflects the overall picture in the Thoroughbred industries in both countries and hemispheres (Rao and Swamy, 1990), it was influenced to a considerable degree by the time of year when work load allowed the survey to be carried out. Therefore, from late March and October onwards in the Northern and Southern hemispheres respectively, the covering season is fully underway, and stud personnel and veterinary surgeons do not always have the time to undertake what may be thought of as nonessential work.

CHAPTER 4.

NEONATAL FOAL EXAMINATION.

4.1 INTRODUCTION AND REVIEW OF LITERATURE.

The neonatal period is generally considered to be from birth to 4 days old in the Thoroughbred foal (Rossdale and Ricketts, 1980; Koterba, 1990a; Young, 1992b). By 4 days the major physiological changes and adaptations are completed and any associated signs of maladjustment have appeared. These limits of the neonatal period mean that any survey of the neonate, including its eyes, must be carried out within 4 days of birth. Since the adaptation rate varies with each body system and can occur rapidly and early in neonatal life, it is essential to observe the foal early in its life and preferably to repeat the observations serially, if any conditions so demand.

As already emphasised in the previous chapter, the only available case history to neonatal abnormalities relates to the foal's intrauterine life and is influenced markedly by gestational and parturient events (Koterba, 1990a; Young, 1992b). Problems during these events can manifest in neonatal ophthalmology as directly caused abnormalities, such as scleral haemorrhages (Munroe, 1988), or, indirectly as disease processes that affect the eyes secondarily i.e. a placentitis leading to a septicaemia and uveitis (Koterba, Brewer and Drummond, 1985; Latimer and Wyman, 1985; Brewer, 1990; Young, 1990a).

4.11 Individual Foal Data.

Examination Period.

As previously stated, because of the rapidly shifting physiological baseline in the neonate, the data retrieved from a clinical and clinicopathological examination of a neonatal foal will vary with time (Rossdale and Ricketts, 1980; Rossdale, Silver and Rose, 1984; Beech, 1985; Koterba, Drummond and Kosch, 1990; Stoneham, 1992). The eye of the neonate also shows these variations through the 4 day period and what is observed by the ophthalmologist must be related to the stage of adaptation (Munroe and Barnett, 1984; Munroe, 1988). Indeed one of the central themes of the survey was to try and understand this ocular adaptation and record it, so that more was known of the ocular shifting baseline. Examples of important areas of the eye in this context include the ocular reflexes, hyaloid apparatus, and resolution of retinal/scleral haemorrhages.

Foal Sex.

As part of the basic data recording of the survey it was considered important to differentiate males from females. Foal sex has been shown to influence birth weight (Platt, 1978), time to stand (Campitelli *et al*, 1982), time of first urination (Jeffcott, 1972), gestational length (Platt, 1978), and possibly parturition difficulties (Simpson, 1992). The incidence of neonatal disease may also be affected by the sex of the foal, for example: male foals have a higher incidence of rupture of the urinary bladder (Richardson and Kohn, 1983; Hackett, 1984; Adams, 1990), and female foals may have a higher occurrence rate of retinal haemorrhages (Munroe, 1988).

Foal Colour.

The incidence of each foal coat colour in this survey was considered important to help detect any connection between coat pigmentation and third eyelid, iris and fundic colouration. This has been suggested previously by work carried out in adults and foals (Gelatt, 1982; Latimer *et al*, 1983; Munroe and Barnett, 1984; Matthews *et al*, 1990a).

4.12 Birth Weight.

In the horse, there is a wide variation in birth weights between breeds, and even within a breed such as the Thoroughbred. Similarly, as already discussed in the last chapter, there exists a wide variation in gestational length. However, it is well recognised by human and equine neonatologists that the combination of the two can help decide on the maturity and possibly "readiness for birth" of the foal (Rossdale and Ricketts, 1980; Koterba, 1990c; Stoneham, 1992). Based on these two parameters, and in association with a full physical and haematological/biochemical examination, it is possible to classify any neonate into certain categories of maturity (Koterba, 1990c). This then allows the clinician to further explore the case in specific areas where abnormalities/disease processes have been recorded in such cases in the past. Some of these problems do affect the eye of the neonate and hence the importance in this survey of assessing foal birth weight and maturity. Some confusion still exists in the terminology which is used. Premature, is a foal displaying immature physical characteristics with a gestational length of less than 320 days. Dysmature, first used in the equine by Rossdale, is used to describe a term foal, which shows signs of immaturity and usually a low birth weight. This is often associated with placental pathology or another cause of intrauterine growth retardation (Rossdale and Ricketts, 1980; Chiswick, 1985; Koterba, 1990c). The connection of neonatal foal normality to foetoplacental health and gestational/parturition history is, as has already been stated in the last chapter, an important one. The human medicine term, Small for Gestational Age (SGA), was not used in this survey, but it does have advantages in that it allows any foal to be classified according to both gestational age and body size; as both premature and SGA, or premature and appropriate for the shortened gestational age (Koterba, 1990c).

The signs of immaturity seen in these premature/dysmature foals, besides low birth weight, are: general weakness or "floppiness" with increasing length of time to stand and nurse; short, silky hair coat; pliant ears and soft lips; meconium staining; abnormal mucous membranes; increased limb laxity and cuboidal bone hypoplasia (Rossdale and Ricketts, 1980). These foals present as High-Risk foals with a high incidence of neonatal infections, congenital abnormalities, asphyxia, and death.

Rossdale (1976) recorded the mean weight for full-term Thoroughbred foals to be 49.6 +/-0.45 kg. He further suggested that mean birth weight was not affected by gestational age after 320 days. In foals of greater than 320 days first born foals had a significantly lower birth weight (mean 43.8 +/-0.45 kg.) than foals born to multiparous mares (mean 50.6 +/-0.45 kg.). Platt (1978) in a survey of Thoroughbred studs found the average birth weight of 796 live foals to be 51.3 +/-6.18 kgs. Single male foals were on average slightly heavier than single females. He suggested that low birth weight was related to intra-uterine growth retardation such as twin pregnancy, placentitis, premature parturition, or foetal abnormality.

Excessive body weight can increase the incidence of abnormalities at parturition (Arthur, 1975; Hillman, 1983; Simpson, 1992). Relative and absolute foetal oversize may occur, requiring human interference, and the possibility of birth trauma to the foal. One such ophthalmic problem is scleral haemorrhages (Munroe, 1988).

4.13 Foal Behaviour and Clinical Examination.

The successful adaptation of the foal to extrauterine existence requires certain physiological changes. These may be anatomical, functional or biochemical, and affect all body systems, including the eye (Rossdale and Ricketts, 1980). The purpose of neonatal examinations on a regular basis (usually days 1-3), as carried out in this survey, is to recognise and confirm these underlying physiological alterations (changing baseline), and to detect any abnormality in these mechanisms at an early stage (so-called "High Risk Foal"). Clinical examination of neonates on a regular basis will also allow prompt diagnosis of secondary disease processes, such as septicaemia, and more effective treatment (Koterba, 1990a; Stoneham, 1992). The importance to this survey of this altered physiology and secondary pathology is that the eye is a good example of a body system so affected. As such, any neonatal eye survey must be aware of the ophthalmic changes related to both its physiology and pathology, and also secondarily to other body system changes. Examples of these three areas are seen in the resolution of the hyaloid system, retinal haemorrhages, and secondary entropion in dehydrated foals.

Besides clinical examination, data collected by the stud on the time to stand and suck from the mare can be useful additional information. A foal appears to have an inborn pattern of behavioural responses by which it stands. Several attempts may be made before the foal succeeds. Thoroughbred foals stand on average within 60 minutes of birth, although considerable variation does occur: 15-165 minutes (mean 57 minutes) (Rossdale, 1967; Rossdale and Ricketts, 1980; Campitelli *et al*, 1982; Crowell-Davies, 1986; Koterba, 1990a). In Thoroughbred foals (Rossdale, 1967; Campitelli *et al*, 1982) fillies stood, on average, 14.3 minutes sooner than did colts. Initially, Rossdale (1967) thought that because fillies are on average slightly lower in birth weight than colts, that this might be the cause of the difference. Subsequently Rossdale (1973, unpublished, quoted in Rossdale and Ricketts, 1980) found no significant relationship between foal birth weight and the time taken to stand. For clinical purposes foals taking longer than 120 minutes or 2 hours to stand for the first time are regarded as potentially abnormal (Rossdale and Ricketts, 1980; Crowell-Davies, 1986).

The time taken for the foal to gain the necessary co-ordination and reflexes for nursing or sucking from the mare's teat varies between breeds (Crowell-Davies, 1986), but in Thoroughbreds nursing first occurs at a mean time of 111 minutes post-partum (range 35-420 minutes) (Rossdale, 1967; Rossdale and Ricketts, 1980). Once established, the nursing behaviour rapidly strengthens so that it occurs regularly at intervals of 30-60 minutes. Foals taking longer than 3 hours to suck should be considered potentially abnormal (Rossdale and Ricketts, 1980). Failure to nurse and consume adequate levels of colostral antibodies within 6-12 hours, is one of the major causes of failure of passive transfer of immunoglobulins and subsequent life-threatening infections (Jeffcott, 1974; Le Blanc, 1990).

The relationship between neonatal conditions and the pre- and intranatal environment of the foetus is, as has been shown, very complex. Add to this, the rapidly changing physiological baseline and the unique response of the neonatal foal to abnormalities and stimuli, and it becomes obvious that neonatal disease of the equine requires some special classification. The following classification was introduced by Rossdale (1972a and b) and modified/expanded by Rossdale and Ricketts (1980) and Young (1992a). See Table 4.1

	Characteristics/Signs	**Aetiology**
Group 1 **Infective or Septicaemic Conditions**	Within 24 - 48 hours Lethargy, gradual loss of suck reflex, pyrexia. Signs of localising infections e.g. pneumonia, diarrhoea. Eye lesions. Rapid dehydration. W.B.C. changes. Failure Passive Transfer. Hypoglycaemia.	Any mare genital tract organism including beta haemolytic Streptococci, Gram negative bacilli, EHVI. Septicaemia with localising bacteraemia.

Group 2		
Non infective conditions characterised by gross disturbances in behaviour:	First 12 hours Complete loss of suck reflex. Inability to recognise mare.	
Neonatal Maladjustment Syndrome	340 day gestation. Blindness, convulsions, coma, irritation, wandering. Respiratory distress.	Not fully understood. Hypoxia, circulatory disturbances, birth trauma. Cerebral oedema &/or haemorrhage
Prematurity	300 - 320 day gestation.	See earlier section on body weight.
Dysmaturity	>320 day gestation.	
Meconium Retention	Straining, colic. Abdominal tympany.	Unknown.

Group 3. **Developmental**	Anatomical abnormalities Ruptured bladder/urachus. Patent urachus. Limb deformities. Parrot jaw. Cleft palate. Cardiac defects. Ocular defects. cataracts. entropion. microphthalmia. Scrotal / Inguinal hernias etc.	Usually due to a subtle interplay between genetic and environmental factors on foetus and early neonate.
Group 4. **Immunological**	Conditions characterised by reactions between maternal and foetal tissues. Within 6 - 72 hours. Lethargy, anaemia, jaundice, dyspnoea, collapse. Low PCV and Haemoglobin.	Incompatible blood group reaction between serum antibodies of dam (colostrum) and erythrocytes of foal.

Any foal abnormality detected during the survey was classified under this system.

4.2 RESULTS AND STATISTICS.

4.21 Individual Foal Data.

Numbers of Foals.

A total of 169 neonatal Thoroughbred foals were examined. 151 foals (89%) were examined in the two centres in the U.K. and 18 (11%) in New Zealand. Both eyes were included in the survey giving a total of 338 eyes investigated.

Examination Period.

The distribution of foals in each first examination period is shown in Table 4.2

Examination Period. (Hours from Birth)	No. of Foals.
0 - 24	109 (64.5%)
24 - 48	44 (26%)
48 - 72	12 (7%)
72 - 96	4 (2%)

All the foals in the survey were first examined within the neonatal period of 0-4 days, and 90% within 2 days of birth. Any foals requiring further examinations were followed on a variable basis depending on the reason e.g. neonatal illness 2-4 hourly regimen; retinal haemorrhages every 2-3 days.

The relationship of first examination time to the ophthalmic changes is recorded in later chapters.

Foal Sex.

Of the 169 foals, 81 (48%) were male (colts) and 88 (52%) female (fillies). In the N.Z. bred foals (18) twice as many males as females were born.

Statistically there was no significant relationship between foal sex and birthweight but a trend existed of slightly more female foals in foal size 1 (smaller). There was no relationship between foal sex and abnormal behaviour, time to stand or suck, or foaling catergory. However, male foals were overrepresented in catergory 3 foalings. Sex did appear to significantly affect gestational length, with males tending to be overdue and rarely premature.

Foal Colour.

The distribution of foal colours is shown in Table 4.3

Bay	103	(61%)
Chestnut	45	(27%)
Grey	12	(7%)
Brown	1	
Bay-Brown	7	(4%)
Black	1	
Total	169	

The distribution of colours is very similar to the mare and stallion (figure 19), and probably reflects the general spread of Thoroughbred population coat colour. Significantly more grey and less chestnut foals were born in New Zealand than in the U.K.

The relationship of coat colour to pigmentation in the eye is discussed in the relevant chapters.

4.22 Foal Birth Weight.

The birth weight of each foal was placed in one of four categories and is shown in Table 4.4 and Figure 24.

Birth Weight (kgs)	Male	Female	Total	
<45	4	2	6	(3.5%)
45 - 50	55	62	117	(69%)
51 - 56	17	16	33	(19.5%)
>56	5	8	13	(7.5%)

There was no statistically significant relationship between the sex of the foal and its birth weight. New Zealand bred foals were over represented in the 51-56 and >56 kg. categories.

Foal size was related to the incidence of abnormal behaviour, specifically in foals less than 45 kgs, and also to the time to stand and suck. The <45 kg foals had prolonged times to rise and nurse. Foal size and maternal parity were statistically related as described in Chapter 3. Foal size had no correlation with pregnancy abnormalities or, overall, with foaling category. Individual foaling categories, however, were strongly associated with foal size. Category 3 foalings (foetal oversize) were overrepresented in the 51-55 kg. group and abnormal/miscellaneous foalings were more common in the <45 and >56 kg. groups.

4.23 Foal Behaviour and Results of Clinical Examination.

Of the 169 foals in the survey, 22 (13%) were recorded as having abnormal behaviour. Table 4.5 details the various abnormalities that were found, classified into the four neonatal disease groups.

Table 4.5

			% of all foals
Group 1	Infective	2	(1%)
Group 2	Behavioural	12	(7%)
Group 3	Developmental	6	(3.5%)
Group 4	Immunological	0	
Others	Trauma	2	(1%)
Total		22	(13%)

The most common abnormalities were in Group 2 (7%), and were mainly related to dysmaturity (figure 25). Developmental abnormalities in Group 3 (3.5%), often involved limb deformities (figure 26). Only 2 foals (1%) had infective (Group 1) abnormalities. The incidence of foal diseases in New Zealand (28%) was significantly higher than in the U.K. .

The times to stand and suck for the foals in this survey are shown in Table 4.6

Time to stand	**<1 hour**	**1 - 3 hours**	**>3 hours**
	151	10	6
	(89%)	(6%)	(3.5%)
Time to suck	**< 2 hours**	**2 - 4 hours**	**>4 hours**
	128	22	17
	(76%)	(13%)	(10%)

2 foals were not recorded because parturition and immediately post-partum were not attended.

There was a very strong statistical relationship between the time to stand and suck, and foal behaviour, both times being increased in abnormal foals. Abnormal foal behaviour and prolonged time to stand/suck were overrepresented in foaling categories 4 and 5. Foal behaviour and time to stand/suck are not significantly related to the foal sex, maternal parity or gestational history, although there is a slight trend for more foals with abnormal behaviour in the pregnancy abnormality group. As previously reported, foal size and abnormal behaviour are statistically correlated.

The details of the abnormal foals in this survey are shown in Table 4.7.

Foal	Exam Time (hrs)	Body Wt. (Kg)	Clinical Examination
30	14	40	Savaged by mare. Multiple bites.
48	84	50	Diarrhoea for 24 hours.
63	12	>60	Congenital flexor deformities hindlimbs. Assisted to stand. Retained meconium. Corneal oedema. No ulceration.
64	30	45	Dull, weak, dumb. Prolonged period to stand/suck. Nasogastric feeding 24 hours. Placenta NAD.
65	12	45	Dysmature, weak. Slow to stand/suck. 9 days early. Mare poor lactation.
66	39	45	Dull, dumb, decreased respiratory rate. Stand/suck within normal limits.
67	19	45	Dull, weak. Stand/suck within normal limits.
68	33	45	Weak, poor suck. Nasogastric feeding 4, 6, 8, 10, 12 hours. Mare abnormal uterine and placental shape with weak foals.
69	3.5 and 120	45	Dysmature, respiratory distress, excessive laxity carpus/tarsus. Unable to stand/suck 36 hours. Nasogastric feeding. Mild neurological signs. Mare placentitis and laminitis.
70	12	<45	Unattended foaling in underweight mare. Weak, emaciated, low body weight, dull foal. Unable to stand/suck.

Foal	Exam Time (hrs.)	Body Wt. (Kgs)	Clinical Examination
71	6	<45	All four limbs flexor tendon flacidity. Prolonged time to stand/suck (6 hrs.).
72	6	45	Normal foal unable to suck. Nasogastric feeding 2, 4, 6 hours. On suck 8 hours.
73	72	<45	Low body weight, weakness. By 5 days septicaemia leading to uveitis/septic arthritis/myositis. Died day 15.
74	25.5	45	Dummy, chewing, yawning, wandering, abnormal sleep patterns. Nasogastric feeding 2.5 hours. Stand/suck 4.5 hours. Normal by 24 hours. Congenital papilloma.
110	4.5	>60	Dull. Bilateral forelimb flexor deformity involving both digital flexors. Treated and normal in 48 hours. Helped to stand for 12 hours.
111	10	50	Neonatal maladjustment syndrome. Convulsions, barking, opisthotonus, extensor rigidity, 2.5 hours after foaling. Treated. Stand/suck within 48 hours.
113	4	50	Contracted foal syndrome. Bilateral forelimb/hindlimb flexor deformities including carpus and hock. Scoliosis. Unable to stand. Euthanasia.
119	12	50	Unattended foaling in caslicked mare. Foal comatose, hypothermic, severe self-inflicted trauma. Intensive care. Died in 24 hours. PM: severe damage to eyes, poorly inflated lungs, chest wall bruising, extensive CNS damage and congestion. ? NMS.
142	17.5	60	Bilateral hindlimb and mild RF fetlock flexor deformity. Nasogastric feeding for first 24 hours until treatment allowed foal to stand and suck.
122	13	50	Protruding tongue, midline ranulae, suck to one side. Resolved 7 days. Overdue uniparous mare.
151	11	55	Dumby. Wandering. Mild head tilt. Prolonged time to suck. Nasogastric feeding. Normal 24 hours.
162	15.5	55	Windswept, weak hindlimbs. Normal time stand/suck.

4.3 DISCUSSION.

4.31 Individual Foal Data.

Examination Period.

Of the 169 foals, 64% were examined within 24 hours of birth and a further 26% in the next 24 hours. All 169 foals were examined as neonates which is in marked contrast to the three previously published eye surveys in foals (Barnett, 1975; Koch *et al*, 1978; Latimer *et al*, 1983). 90% of the foals were examined by the end of the second day, which is before most insurance examinations take place on the third day of life (Stoneham, 1992). Comparison of the ophthalmic findings at various examination times allows a picture of the changing physiological baseline of the eye to be built up. The picture was clarified by the repeat examinations undertaken in selected foals. The changes will be discussed under the separate ophthalmic headings.

Foal Sex.

There were slightly more females than males in the survey, but in New Zealand twice as many male foals were recorded. This may have been an effect of the small numbers in this group. The survey results did not confirm the findings of Platt (1978) that foal sex affects birth weight, or Campitelli *et al* (1982) that it is related to abnormal foal behaviour or time to stand. It did, however, confirm Platt's (1978) suggestion that male foals had a significantly longer gestation period, and this may be one reason why male foals more frequently lead to foetal oversize at parturition. The relationship of foal sex to ophthalmic changes will be discussed in later chapters.

Foal Colour.

The spread of coat colours in the foal was statistically strongly correlated with parent coat colour and has already been discussed. The higher incidence of grey coat colour in New Zealand foals is thought to be due to the older bloodlines present in that country. These lines, mainly U.K. based, have more grey horses in them than the recent U.S.A. derived Thoroughbreds now predominating in the U.K. The influence of coat colour on ophthalmic structure pigmentation will be discussed in later chapters.

4.32 Foal Birth Weight.

89% of the foals in this survey had a birth weight between 45 and 55 kgs. giving a distribution and mean which very closely mimicks the work of Rossdale (1976) and Platt (1978). As already described in Chapter 3, and by Rossdale (1976), foal birth weight and maternal parity are correlated. There appeared to be no relationship between foal sex and birth weight, but those foals in this survey bred in New Zealand were slightly larger. This may be due to the differences in bloodlines, with the New Zealand Thoroughbred tending to be larger and heavier boned than the U.K. counterpart; or to nutrition and climate. The results of this survey confirm that low body weight and abnormal foal behaviour, including times to stand and suck, are strongly related statistically, but foal size and abnormal gestational history are not. Since the majority of abnormal gestations in this survey were related to gestation length (see Chapter 3), it suggests that the majority of low birth weight foals with abnormal foal behaviour would be classified as dysmature, or small for gestational age, and not premature. Most dysmature, low birth weight foals, are associated in the literature with intrauterine growth retardation (IUGR) (Platt, 1987; Koterba, 1990c), but not overall in this survey with any of the more obvious causes, such as twin pregnancy or placentitis. Other causes of IUGR have been suggested (Chiswick, 1985; Koterba, 1990c), the most common being uteroplacental vascular insufficiency, possibly at the microscopic level.

Although, in general, the connection between foal birth weight and foaling category was tenuous, that between birth weight and category 3, or foetal oversize, was clearer. This confirms the earlier work of Arthur (1975), Hillman (1983) and Simpson (1992). The links between categories 4 and 5, and the smallest and largest birthweight groups is perhaps not surprising when considering the importance of the foetus in initiating, controlling and undertaking parturition. A weak, small, possibly metabolically abnormal foal, and an oversized, rather "cramped for space" large foal, are both more likely to have parturient problems.

4.33 Foal Behaviour and Clinical Examination.

The incidence of abnormal neonatal foal behaviour and findings on clinical examination in this survey was 13%. There is no published work on the incidence of foal diseases in the general population of foals, although Platt (1973) presented work on the aetiological aspects of perinatal mortality in the Thoroughbred.

Many of the figures on the incidence of neonatal disease are derived from neonatal intensive care units where the population of foals treated is biased heavily towards sick and ill animals (Koterba, Drummond and Kosch, 1985 and 1990; Koterba and Drummond, 1988). A good example of this is shown by the incidence of infective (Group I) conditions in this survey (1%), as compared to that seen in the intensive care hospital in Florida (U.S.A.) where 40% of sick foals admitted were confirmed to be septicaemic, or have local infections such as pneumonia, enteritis, or joint infection (Brewer, 1990). The incidence of overall foal abnormality in this survey will have been affected by the breed (Thoroughbred); standard of stud management (generally high); parturient and neonatal care and supervision (good); and regular veterinary examination, including blood samples, of all foals. The significantly higher incidence of neonatal disease in New Zealand is likely to be related to less care and supervision of foals in that country, both by lay persons and the veterinary profession. This is partly an economic problem and also a matter of education. There was no statistical effect of examination time on the incidence of disease in this survey probably because of the careful history taking and the monitoring of the foals for the majority of the neonatal period, irrespective of the examination timing.

The individual incidence of neonatal diseases is shown in Tables 4.5 and 4.7. As already mentioned, the level of Group I conditions is low as compared to other published work (Morris, 1984a & b; Carter and Martens, 1986; Koterba and Drummond, 1988). Possible reasons include the differences in population, standard of initial neonatal care, environment, regular use of prophylactic broad spectrum antibiotics, careful monitoring of immunological status and supplementation by colostrum, plasma or whole blood as necessary. Failure to recognise the presence of infection may have also been a factor, since not every foal was submitted to a sepsis score analysis (Brewer and Koterba, 1988), or blood culture (Koterba, Brewer and Tarplee, 1984; Brewer, 1990). Any foal that died was, however, subjected to a rigorous post-mortem examination.

Behavioural, or Group 2, disorders were recorded in 7% of all foals. Of these, 1 foal was a confirmed Neonatal Maladjustment Syndrome (NMS) and 3 others had signs suggestive of NMS, although all of these could have had neurological signs related to immaturity. Rossdale and Ricketts (1980) suggested an incidence of 0.75% of all full term births in the Thoroughbred developed NMS. Clabough and Martens (1985) reported a slightly higher incidence of up to 2% of all Thoroughbred births. The figures for this survey would be within these limits. Up to 11 of the foals in Group 2 appear to have had varying degrees of immaturity and, as none were premature on gestational dates, these would be termed dysmature. Many were slow to stand and suck, were depressed and dull, had low body weights, and haematological/biochemical tests suggestive of immaturity. These foals were considered high risk foals (Koterba, 1990a), particularly as regards possibilities of secondary infections, and were placed into an intensive care programme. The strong correlation between foal size and abnormal behaviour in this survey is a reflection of the large numbers of immature/dysmature foals in this group. The cause of these dysmature foals was sometimes obvious; intrauterine growth retardation i.e. placentitis, abnormal placental shape, undernourished mare, or treatment of mare when pregnant. However, on other occasions the cause was less obvious. In some foals it was thought to be related to immaturity of body systems, such as adrenal cortical and other endocrinological dysfunction (Rossdale, 1988; Shaftoe, 1990), cardiorespiratory system including lung surfactant (Rose, 1988), gastrointestinal tract (Wilson and Cudd, 1990), and musculoskeletal system (Adams, 1990). The high incidence of dysmaturity in this survey (6%) compared to the only recorded incidence of 1% in Thoroughbreds (Rossdale and Ricketts, 1980) is interesting and may be due to overenthusiastic attempts at diagnosis by the author, and/or increasing availability of information on, and recognition of, these conditions leading to a better diagnosis. Koterba and Drummond (1988) suggested that over 30% of foals admitted to a neonatal intensive care unit were either premature or dysmature, many of them also developing infections.

Developmental disorders were recorded in 6 foals (3.5%) in this survey, which is the incidence cited by Rossdale and Ricketts (1980). All of the foals in this survey were suffering with various forms of congenital flexor deformities (Leitch, 1985; Adams, 1990; Ellis, 1992). Most of these were self correcting or resolved with treatment in 24-48 hours. Their significance lay in the fact that they prolonged the time to stand and suck, and often affected foals required assistance to stand/suck, or nasogastric tube feeding. In this group particularly, but also in the majority of the abnormal foals, there was a very strong statistical relationship with the time to stand and suck, with both times being prolonged in abnormal foals.

None of the foals had immunological disorders that were detectable within the limits of the examination procedure. This is not surprising because of the low incidence of this disorder in the Thoroughbred population of less than 0.5% (Rossdale and Ricketts, 1980). Subclinical cases can be missed if blood analysis is not undertaken, but in this survey no cases were evident on routine haematological examination. Many of the pregnant mares in this survey were also subjected to pre-partum blood typing for the presence of developing antibodies to the foal's blood group. A rapidly increasing titre warned the stud personnel to restrict access of the foal to the mare's colostrum.

The two other foals in the survey with abnormalities were classified as being due to trauma. One foal had an injury to its tongue thought to have been caused by compression during foaling. This was self resolving. The other foal was savaged by the mother before clinical examination at 14 hours. Bites occurred down the neck and back. Foal rejection (Crowell Davis and Houpt, 1986) in its most serious form can involve such biting and may occur every year in some mares. This mare was uniparous and had a particularly aggressive temperament. She had allowed the foal to suck whilst being held and observed for the first 6-8 hours, and was considered safe to leave alone with the foal. Subsequent events proved this to be incorrect. Intervention by the stud staff rectified the situation, and the foal/mare bond was re-established.

The times to stand and suck for foals in this survey were broadly in line with previous work (Rossdale, 1967; Rossdale and Ricketts, 1980; Campitelli *et al*, 1982; Crowell-Davis, 1986). 89% of foals stood without assistance within 1 hour of foaling, with a further 6% in the next 2 hours. The previous work that suggested that time to stand might be related to foal sex (Campitelli *et al*, 1982) was not confirmed, but Rossdale and Ricketts' (1980) statement that foal birth weight and time to stand are not related was upheld. 76% of foals had nursed from the mare in less than 2 hours, with a further 13% in the next 2 hours. This, again, confirms the previous work of Rossdale (1967).

The time for foals to stand and suck in this survey, as previously stated, have a strong statistical relationship with foal behaviour. The times are significantly increased in abnormal foals, especially those with Group 2 abnormalities, and Group 3 flexor deformities. They are confirmed as useful parameters to monitor on a stud farm, alongside gestational age, body and placental weight, and body temperature. Foal behaviour was also related to foal body weight, again particularly in Group 2 disorders. They are also related to foaling categories 4 and 5 and possibly, abnormal pregnancy. This confirms previous statements regarding influence of parturition and gestation on neonatal health. Foal behaviour, as confirmed earlier, has no relationship with foal sex or maternal parity.

CONCLUSION for Chapters 3 and 4.

The purpose of the information recorded and discussed in Chapters 3 and 4 was: to generate a database for each foal so that it could be identified and traced, if required, later in its life; to carefully assess the gestational and parturient factors that may affect the neonatal foal and particularly its eye; and to identify foal disease processes that may directly or indirectly contribute to variations in the morphology of the neonatal foal's eye.

In subsequent chapters, the different areas of information gained by the various parts of the ophthalmic examination, are related both to themselves, and to the data generated in the last two chapters. Ultimately, not only the type and incidence of eye anomalies/abnormalities was searched for, but also some idea of their aetiology and pathogenesis.

CHAPTER 5.

VISION AND OCULAR REFLEXES.

5.1. INTRODUCTION AND REVIEW OF LITERATURE.

5.11 General Introduction.

The assessment and interpretation of vision and ocular reflexes is an important part of the ophthalmological and neurological examination of any animal. Abnormalities causing blindness or changes in reflexes can occur both within the eye, and also remote from it in the central nervous system. Problems of interpretation of findings, particularly in the foal, are common because of the different behavioural responses, handling difficulties and the relative slowness of development of ocular reflexes toward the adult model. Neuro-ophthalmic testing in this survey was carried out, as previously described, at the start of the foal examination (both ophthalmic and general) so that misinterpretation could be minimised.

5.12 Vision.

The equine eye has developed a number of anatomic and physiologic features to suit the special needs of the species (Davidson, 1991). The vision of the horse is designed to avoid predators while grazing and allow fast flight on a difficult terrain (Blogg, 1985). To acheive this, the horse has developed a large visual field (greater than 350°) which is monocular, and a limited visual binocular field estimated to be 65° (Davidson, 1991) (figure 27). The equine retina has two areas of more acute perception upon which light is focused for forward and lateral vision. The area centralis serves forward binocular vision, and the second band-like "visual streak" is associated with monocular lateral vision (Blogg, 1985). The presence of these two areas and the dynamic accommodative ability of the horse's eye (albeit limited), plus recent studies, have discredited the classic theory of equine visual optics involving static accomodation, or the ramp retina theory (Sivak and Allen, 1975; Blogg, 1985; Davidson, 1991; Roberts, 1992c). Lateral and peripheral vision are further broadened by the horizontal pupil of the adult horse and the heightened sensitivity of the peripheral retina to movement (Blogg, 1985; Lavach, 1990).

Night vision is enhanced by a choroidal tapetum and a retina with a preponderance of rods (Davidson, 1991).

Refractive errors have a questionable effect on horses, but have been recorded in the adult, most of which were myopic (Lavach, 1990; Roberts, 1992c). Myopia in 14 mares and 75% of their foals was detected and the defect thought to be hereditary (Hamori, 1941, quoted by Lavach, 1990).

Colour vision studies in the horse are limited and subjective, but suggest a reasonable ability to distinguish green, yellow and possibly blue, and a poor ability to detect red. (Grzimeik, 1952 quoted by Blogg, 1985; Ducker, 1964, quoted by Lavach, 1990; Beaver, 1982; Lavach, 1990; Roberts, 1992c).

The horse has two visual pathways: one for binocular (forward) vision via the geniculostriate pathway, and one for monocular (lateral) vision via the tecto-fugal pathways. The binocular pathway needs visual input to become established and hence the importance of early cataract surgery to remove total lens cataracts, and allow the return of retinal stimulation in foals. The monocular pathway is established at birth, largely independent of visual input (Blogg, 1985).

The central visual pathway has been described (Petersen Jones, 1989) (figures 28 & 29). The interaction of a photon of light with a photoreceptor within the retina hyperpolarises it ("turns it off"). These photoreceptors synapse with bipolar cells and then ganglion cells, of which there are many different sorts, each of which responds differently to signals received. Various other cells within the retina help integrate the information received by the ganglion cells, and by this complex mechanism convert photons into an electrical message which is conveyed by the axons of the cells to the central nervous system. These axons from the ganglion cells travel within the nerve fibre layer of the inner retina and come together to form the optic nerve. This passes through the lamina cribosa of the fibrous coat of the eyeball at the optic disc, and forms the retrobulbar portion of the optic nerve. This contains axons which transmit information for conscious visual perception and also separate axons which form the afferent (sensory) arm of various reflexes e.g. pupillary light reflex, visual fixation reflexes.

The two optic nerves (left and right) enter the skull through the optic canals and join to form the optic chiasma. In large animals, including the horse, 80 - 90% crossing over of optic nerve fibres occurs at the chiasma (Mayhew, 1988). Therefore, vision in one eye in the horse is perceived mainly in the visual cortex of the opposite (contralateral) cerebral hemisphere. However, because of the need for some binocular vision, some optic nerves must project to the ipsilateral hemisphere. After the optic chiasma, the fibres concerned with vision pass within the optic tracts to the lateral geniculate nuclei, within the diencephlon, where they synapse with other neurones that project to the occipital (visual) cortex, via the optic radiation (Hakanson and Merideth, 1987b; Petersen Jones, 1989) (figure 29).

The assessment of a horse's vision can be difficult. In the foal this is even more so because the neonatal foal is unused to handling and can become easily agitated. The responses of neonatal foals, behaviourly, are different from adults (see Chapter 4) and must be understood before assessment of vision can be attempted (Adams and Mayhew, 1985; Green and Mayhew, 1990). Vision loss in foals may not be noted until the foal leaves the dam. In the adult horse vision is tested using the maze or obstacle course. Each eye may be blindfolded in turn and the horse is handled on a long rein, by a new handler and on its own (Blogg, 1985; Petersen Jones, 1989; Lavach, 1990). The same technique can be used in older and weaned foals, but in neonatal foals close observation of the free foal's behaviour in a large box or small paddock (Latimer and Wyman, 1985) is more effective. The presenting history, often helpful in assessing older animals' vision, is lacking in neonates. The cotton ball or wad of paper test, where these are dropped in front of the horse or foal and it follows them to the ground (Rebhun, 1991), has proved unreliable in assessing vision in horses (Lavach, 1990). Palmer (1976) also used this method in confirming the presence of the fixating reflex, which is an obligatory turning of the head and eyes towards a moving object.

The menace, or eye preservation response, can also be used to test the visual pathways in animals (Hakanson and Meredith, 1987b; Mayhew, 1988; Petersen Jones, 1989).

5.13 The Menace Response or Reflex.

In the menace reflex, the eye is "threatened" with a hand or object, and the visual animal will blink and usually withdraw its head (Hakanson and Meredith, 1987b; Mayhew, 1988; Petersen Jones, 1989) (figures 2 & 30). Great care is required not to touch the eye or produce air currents which may be felt by the cornea. In addition to a normal central visual pathway (afferent arm), the menace reflex has an efferent arm which requires an intact motor cortex, cerebellum and facial (VII) nerve (Petersen Jones, 1989). It is because of this efferent pathway that it can be assumed that the visual input reaches the visual cortex. Some stoic, depressed, or even excited animals may not respond with eyelid closure, or they may keep the eyelids closed (Mayhew, 1988). Partial, unilateral blindness can be difficult to detect and testing each eye in turn, with the use of unilateral blindfolding, may be necessary. Assessing medial and lateral visual fields of each eye is possible. Because of the high crossover of afferent fibres at the chiasma in the horse, for all practical purposes, vision tested in one eye by the menace reflex is being perceived in the opposite (contralateral) visual cortex of the cerebral hemispheres (Mayhew, 1988). The menace reflex may be absent or reduced in young animals (Petersen Jones, 1989).

The menace reflex was present in a survey of 144 foals, ranging in age from 5 days to 19.5 weeks (Latimer *et al*, 1983). Others have stated that the reflex develops in the first 2 weeks after birth and is not reliable during this time (Adams and Mayhew, 1984; Blogg, 1985; Hakanson and Meredith, 1987b; Green and Mayhew, 1990; Lavach, 1990; Whitley, 1990). Green and Mayhew (1990) suggested that although the menace reflex was absent in young foals, an alert foal of only 1 day old will withdraw its head from a menacing gesture, but not blink.

5.14 Pupillary Light Reflex (PLR).

The diameter of the pupillary aperture is controlled by the constrictor pupillary muscles, innervated by the parasympathetic fibres in the oculomotor nerve, and by the dilator muscles of the pupil, which are innervated by the sympathetic fibres from the cranial cervical ganglion (figures 31 & 32). These innervations originate from higher centres in the brainstem, and change pupil diameter in response to light (oculomotor nerve), fear and excitement (sympathetic) (Mayhew, 1988). The afferent side of the reflex consists of ganglion cells in the retina not concerned with conscious perception of vision, whose axons follow the visual optic tracts until they branch off just before the lateral geniculate bodies. Just as in vision fibres, more than 80-90% of those concerned with PLR decussate and pass to the pretectal nuclei. Here they synapse with post-synaptic fibres, then passing to the parasympathetic nucleus (oculomotor). From here a majority of fibres cross from the pretectal nuclei to the contralateral oculomotor (back to the same side of the body from where the stimulus originated). There is also some direct communication between the two pretectal nuclei involved. Fibres from the pretectal nuclei synapse in the oculomotor nucleus with the cell bodies of the efferent fibres which pass in the oculomotor nerve to the eye on the same side. The fibres pass via the ciliary ganglion, where they synapse, post-synaptic fibres passing via the short ciliary nerves to innervate the circular muscle of the iris (pupillary constriction), and smooth muscle within the ciliary body (parasympathetic). The sympathetic nervous system, which plays no direct part in the pupillary light reflex, innervates the radial smooth muscle of the iris (Petersen Jones, 1989).

The PLR is not a guide to the state of an animal's vision, but may be used to localise lesions within the central visual pathways. Animals can be blind with normal PLR and, conversely, have normal vision with fixed dilated pupils (Petersen Jones, 1989).

The size and symmetry of the resting pupil is related to the amount of ambient light (dilated in the dark), the emotional state of the patient (dilated in fear), and the effect of any lesion of the iris e.g. uveitis/synechiae. The normal response to light directed into the eye is constriction of both pupils, referred to as a direct response in the same (ipsilateral) eye into which the light is shone, and a consensual or indirect response in the other (contralateral) eye (figures 3 & 33). The pathway for this response is as previously described, with crossover and interconnections occurring at the level of the thalamus, so that both oculomotor nuclei are involved, and hence both pupils (Palmer, 1976; Mayhew, 1988; Petersen Jones, 1989; Lavach, 1990; Gum, 1991). The time and magnitude of the PLR will depend on the brightness of the light, ambient light and the mental status of the horse. Compared to small animals, horses have neither the rapidity nor the magnitude of pupillary constriction to a photic stimulus (Lavach, 1990). This is probably due to differences in structure. Some authors suggest that the magnitude of the consensual response is not as great as the direct (Petersen Jones, 1989). Because of the awkward nature of consensual pupillary light responses in large animals, the swinging flashlight test has been used as an alternative and may demonstrate the slight anisocoria previously discussed (Mayhew, 1988; Petersen Jones, 1989; Lavach, 1990). Blogg (1985) suggested the use of two people to examine the consensual response, particularly in a fractious horse where excitement modifies the response. Direction of the bright light onto the medial and lateral canthus can give information on the fundus associated with lateral vision (nasal retina) and forward vision (caudotemporal retina). Optic nerve fibres from the nasal retina decussate at the chiasma, but temporal fibres do not (Blogg, 1985).

All foals are said to exhibit direct and consensual pupillary light reflexes (Latimer and Wyman, 1985; Adams and Mayhew, 1990; Green and Mayhew, 1990). The degree of PLR response does not correlate with the level of excitement at the time of examination (Latimer, *et al*, 1983), provided a bright light source is directed towards the temporal fundus. However, these results were from surveys of foals greater then 5 days old, and others have noted that both direct and consensual PLR are absent at birth, and are sluggish and incomplete for at least 48 hours (Munroe and Barnett, 1984; Blogg, 1985; Whitley, 1990; Ketring, 1992). Excitement, according to Lavach (1990), Green and Mayhew (1990) and Whitley (1990), may affect the degree of PLR because of increased sympathetic discharge.

5.15 Blink and Photometer Reflexes.

Palmer (1976) reported on a reflex closing of the eyelids when a bright light was shone into the eye (photometer reflex) which he suggested was present at birth. Adams and Mayhew (1985), and Green and Mayhew (1990) also described the same reflex, but called it "the blink to light response" and Scagliotti (1990), the "dazzle reflex" (figure 3). Palmer (1976) thought the reflex probably was dependent on the same afferent pathway as the fixating reflex, but the efferent was through the facial nerve (VII).

Blogg (1985) described the blink reflex as the reflex closure of the eyelids in response to gently touching each canthus. He suggested that this tested the function of the trigeminal and facial nerve, and the orbicularis oculi muscle (figure 5).

5.2 RESULTS AND STATISTICS.

5.22 Vision.

166 foals (98%) in the survey had normal vision at the time of first examination. Three foals were blind (nos. 73, 111, 119). All 3 foals showed serious systemic abnormalities, and were classified as abnormal foals.

Foal 73, when first examined on the third day of its life, had a neonatal septicaemia (Group I). It initially presented with dehydration, weakness, low birth weight, off suck, pyrexia, leucocytosis, neutrophilia, toxic changes in polymorphonuclear leucocytes, and hyperfibrogenaemia. It was blind in the right eye, and only partially visual in the left. It had a bilateral, secondary entropion and a right eye with a severe, acute uveitis, complete miosis, hypopyon and mild corneal oedema. Menace and PLR were absent in both eyes. Bacterial blood culture lead to a pure growth of Streptococcus zooepidemicus. By 5 days post-partum the foal developed a multiple joint, septic arthritis/tenosynovitis. Despite intensive treatment, the foal and right eye deteriorated (collapse of intra-ocular pressure) and euthanasia was carried out (figures 34, 35 & 36).

Foal 111 was a foal with Neonatal Maladjustment Syndrome (NMS) (Group 2) which was blind for 54 hours after starting to convulse 2½ hours post-partum. Anisocoria was present for 12-15 hours from 12 hours after the start of the convulsions. The testing of menace and pupillary reflexes was not possible because the foal was heavily sedated with barbiturates and valium. The foal did have papilloedema, retinal haemorrhages and mild unilateral secondary entropion. The improvement in neurological signs was mirrored by decreasing papilloedema and return of the pupils to bilateral symmetry. However, the blindness persisted for approximately a further 24 hours after the foal stood. After recovery on the third day post-partum, no further visual deficits occurred through the foal's first year of life.

Foal 119 was a dumb version of NMS (Group 2) due to an unattended foaling in a caslicked mare. The foal was found outside, comatose, hypothermic, blind, and with signs of severe self-inflicted trauma. Both eyes had severe blepharitis, traumatically induced bilateral uveitis with posterior synechiae and complete miosis, negative menace and PLR, conjunctivitis and chemosis, episcleral injection and fibrinous/haemorrhagic debris in the anterior chamber and on the anterior surface of the lens. The foal died within 12 hours due to a secondary respiratory infection. Post Mortem examination confirmed multiple pathology consistent with a secondary septicaemia/bacteraemia (figures 37, 38 & 39).

Because of the small numbers of non-visual foals no statistics were carried out on this group.

5.23 Menace Reflex.

The menace response was present in only 6 foals (1, 36, 48, 59, 93, 128). Statistical analysis was attempted, but the small numbers involved make this difficult, and the interpretation of results requires care.

There appeared to be no significant relationship of menace response to foal sex, size or behaviour, abnormal pregnancy, or foaling category. There was a connection between menace response and examination time with the likelihood of a positive response increasing with the age of the foal. Detailed analysis of the individual foal data tends to reinforce this statement. Those two foals (1, 93) which were in the 0-24 hours, and one of the two foals (36) which were in the 24-48 hour examination period, all were graded as a +/- response (marginal). The other three foals were graded + (definite) at 24-48 hours and 72-96 hours.

The presence/absence of a menace response appeared to have no statistical relationship with any other ophthalmic reflex, structure or abnormality.

5.24 Pupillary Light Reflex (PLR).

The numbers of foals within the categories of PLR previously described in Chapter 2 are shown in Table 5.1

PLR	27 (16%)
PLR abn.	134 (80%)
No PLR	6 (4%)
Unrecorded	2

The consensual and direct PLR categories were exactly the same as those shown above i.e. PLR abn. had 134 consensual and 134 direct. The only slight difference in the consensual groups were that the contralateral pupil was very marginally less constricted than the ipsilateral pupil at the end of the reflex.

Of the 6 foals with no PLR reflex of any type, 3 were the blind foals previously described. The other 3 foals (35, 45, 69) were all visual, menace negative, blink and palpebral positive, and were examined less than 15 hours post-partum. 2 were normal foals but one was dysmature, had mild central nervous system abnormalities including papilloedema, and was born to a mare with placentitis. With treatment it recovered to normal in 4 days, when it had a strongly positive PLR.

The rapidity of the PLR was recorded and is shown in Table 5.2

Negative	Slow	Sluggish	Rapid	Unrecorded
6	121	19	21	2

There is a strong statistical relationship between the category of pupillary light reflex and the rapidity of response. None of the positive PLR group were in the slow category, the majority being in the rapid section. Those with PLR abn. reflex were highly correlated with the slow group and to a lesser extent the sluggish group.

There is no relationship in this survey between the category or speed of PLR response, and the presence of corneal opacity, scleral or retinal haemorrhages, or menace response. Iris abnormalities do affect the PLR reflex in this survey. The presence of a hyaloid system appears to be positively correlated to PLR abn. but not to PLR or menace.

Examination time, foal sex and size, foaling behaviour, and gestational history have no effect on the PLR but foal behaviour, including time to stand and suck, does have a slight statistical relationship overall, but especially in the PLR negative group.

5.25 Blink and Photomotor Reflexes.

All 167 recorded foals were positive for the blink reflex. All visual foals were positive for the photomotor reflex.

5.3 DISCUSSION.

5.32 Vision.

The eye of the foal is open at birth and vision is present. 98% of the foals in this survey had normal vision at the time of first examination. The most effective means to test this vision in this survey was close observation of the foal when loose, both in the foaling box, nursery paddock, and moving between the two. Experience in understanding neonatal behaviour was found to be vital in assessing the foal's response to its environment. This test appeared to be very reliable during the early neonatal period before the mare and foal have developed a strong bond, and before the foal has learned and adapted to its environment. These findings confirm the view of Latimer and Wyman (1985), but they also used a simple maze test and menace reflex. Although both of these techniques were used, the former proved difficult to undertake and interpret in the neonatal foal. Leading the foal by a long rein was not well tolerated at this early age and the foal became agitated, losing concentration, and often not completing the course properly. Allowing foals to wander in a small area at liberty where there were a number of innocuous objects, such as bales of straw or plastic buckets, was more effective in determining vision in those foals where observation, as previously described, was inconclusive. The use of the menace response to test vision (Latimer and Wyman, 1985; Mayhew, 1988; Petersen Jones, 1989) in this survey was not effective, since 96.5% of foals were negative for menace reflex at first examination (see section 5.33). The use of pupillary light reflexes in testing vision in the neonatal foal is of questionable value. In this survey, all 3 blind foals were PLR negative, but two of these had iris abnormalities. The other 3 foals with negative PLR were all visual and this is probably explained by the slow development of the reflex in neonatal foals (Munroe and Barnett, 1984) (see section 5.34). Other techniques to assess vision, such as blindfolding (Blogg, 1985) and the cotton ball test (Rebhun, 1991) were not used in this survey because previous experience had confirmed Lavach's (1990) view that they were unreliable.

No attempt was made in this survey to evaluate visual field, any refractive errors (although it was noted in certain foals that to focus on the fundus required a different diopter setting on the direct ophthalmoscope), or colour vision.

The causes of visual impairment, due to ophthalmological and neurological disease, have been recorded in the horse (Kern, 1983; Mayhew, 1988;

Ketring, 1992). Blindness in the foal was described by Ketring (1992). Neurological conditions included transient central blindness in premature foals, Neonatal Maladjustment Syndrome, head trauma, hydrocephalus, viral encephalomyelitides, and bacterial encephalitis/meningitis in neonatal septicaemia. Ophthalmic problems include total mature cataracts, optic nerve hypoplasia, retinal dysplasia, microphthalmia and other multiple ocular abnormalities, uveitis and chorioretinitis, night blindness and optic neuritis. Detailed, serial ophthalmological and neurological examinations are required to specifically diagnose the level of the abnormality (Kern, 1983; Petersen Jones, 1989; Ketring, 1992). Problems in using this series of tests in the foal are associated with difficulties in assessing vision, both unilateral and bilateral, pupillary light responses, and neurological signs.

In this survey, the causes of blindness in the 3 foals were, as is the case in so many neonatal problems, of multiple origins. One foal had a severe neonatal septicaemia with obvious uveitis in the eye in which it was blind. The foal was partially visual in the other eye but had evidence of a chorioretinitis. This may have been present in the other blind eye but the constricted pupil did not allow examination. Menace and PLR reflexes were absent in the blind eye for all 14 days of the foal's life, but were present in the other eye from 5 days post-partum. Foal 111 had a classical Neonatal Maladjustment Syndrome with bilateral blindness, anisocoria, papilloedema and retinal haemorrhages. Heavy sedation made assessment of menace and PLR reflexes impossible. The ophthalmic signs resolved with the neurological system recovery and confirmed their central nervous system derivation (Mayhew, 1988). Foal 119 also had a form of Neonatal Maladjustment Syndrome, confirmed at PM, but the cause of blindness in this case was confused by the severe, trauma-induced, bilateral uveitis and the possibilities of retinal damage.

5.33 Menace Reflex.

96.5% of the neonatal foals in this survey did not have a menace reflex at their first examination. In 3 of the foals with a menace reflex it was described as marginal. These findings confirm those of others (Blogg, 1985; Green and Mayhew, 1990; Whitley, 1990) that the reflex develops in the first two weeks after birth and is unreliable during this time. Latimer *et al* (1983) have disagreed with this by stating that all foals in their survey, of over 5 days old, had a menace reflex. Although none of the foals in this survey were examined for the first time after 4 days, those that were examined for a second or third time after this period often had positive menace reflexes. Menace response and examination time were correlated in this survey, older foals being more likely to have a positive reflex. It seems likely that the foal develops a menace reflex at a variable rate during the first 7-14 days of life. Serial examinations from day 0 to day 14 would be required to confirm this.

The statement that Green and Mayhew (1990) made regarding head movement but no blinking on a menacing gesture in neonatal foals, was not confirmed by this survey. The menace reflex in the neonate requires careful assessment as it can be modified by excitation, and the normal movement of the head in response to auditory or tactile stimuli is abrupt, jerky and exaggerated, leading to confusion. All foals in this survey were therefore tested for the menace reflex early in the examination and responses correlated with degree of excitation caused by handling.

Statistically the menace reflex in this survey had no relationship with any foal, gestational, foaling or ophthalmic reflex, structure or abnormality.

Taking into account these findings of this survey, and the available literature, it seems that the menace reflex is not a reliable guide to neuro-ophthalmological function in the neonatal foal. Testing for vision in the young foal should rely on other techniques.

5.34 Pupillary Light Reflex (PLR).

96% of all foals examined in this survey had a pupillary light reflex. 80% of foals had a PLR that was delayed (PLR abn.). Only 6 foals (4%) had no PLR at all when first examined. In all foals the consensual and direct reflexes were the same, other than a marginal difference in the contralateral pupil in the consensual group.

These findings seem to offer a bridge between the two slightly opposed views on PLR in the foal which were previously quoted. Although surveys of older foals (>5 days) (Latimer and Wyman, 1985) have suggested that both direct and consensual PLR are present, others have mentioned that the PLR is often absent at birth and sluggish/incomplete for at least 48 hours (Blogg, 1985; Whitley, 1990). None of the foals in this survey were examined at birth, and therefore the absence of PLR at this time cannot be confirmed. However, the majority were examined within the first 24 hours and had a positive, if slightly delayed, PLR. Those foals which were negative included 3 blind foals, already discussed (two of these had iris abnormalities), and 1 foal with evidence of mild CNS abnormalities and dysmaturity. Only 2 foals that were clinically normal had a negative PLR. This survey, therefore, suggests that neonatal foals should have a positive PLR. The degree and rapidity of response are related, with the majority of neonatal foals having a slow or sluggish PLR (PLR abn.). The type of response does not appear to change with examination time overall, but there was a trend to rapid PLR (PLR+) in older foals. It was not possible to detect any affect of observable excitement on PLR response (Green and Mayhew, 1990) in this survey. The slight anisocoria seen in the consensual PLR (Petersen Jones, 1989) was confirmed but considered to be insignificant clinically. It was not necessary to use two people, or the swinging flash light test to detect this, as is suggested for large animals, because of the small size of the neonatal foal's head and ease of viewing both eyes at once.

The type and speed of PLR response is not related to the presence of any other ophthalmological finding or reflex, other than iris abnormalities. It was possible to detect a connection between negative PLR and blindness, but this was distorted by the fact that 2 of the 3 blind foals had iris abnormalities, and one of the 2 neurological foals with negative PLR was heavily sedated. The results of this survey cannot confirm that the PLR in the neonatal foal is a useful part of the neurological examination, particularly in localising lesions (Petersen Jones, 1989). The relationship of PLR abn. category to the presence of a hyaloid system is probably due to similar, but not connected, maturation rates. Thus, a foal on the first or second day of its life is most likely to have a PLR abn. reflex and a resolving hyaloid system. The PLR in this project has no connection with foal parameters, other than behaviour, or gestational/parturient history. There is a strong relationship between PLR negative and abnormal foals, due to the iris abnormalities and sedation already discussed. Overall, however, the PLR and foal behaviour are not statistically related, further confirming the limited use of the response as a diagnostic aid in neonatal foals.

The relationship of PLR to resting and post stimulation pupil size and shape will be discussed in Chapter 12.

5.35 Blink and Photomotor Reflexes.

All recorded foals were positive for the blink reflex (Blogg, 1985) and its use in helping to assess neuro-ophthalmological function appears limited, since all blind foals were positive. The photomotor reflex (Palmer, 1975; Green and

Mayhew, 1990) was also positive in all visual foals and probably this reflex gives little new information in these foals.

CHAPTER 6.

THE ORBIT AND GLOBE.

6.1 INTRODUCTION AND REVIEW OF LITERATURE.

6.11 Anatomy.

The horse has a complete osseous rim to its orbit, a feature usually found in horn-bearing animals only (Barnett and Bedford, 1985). It is continuous posteriorly with the temporal fossa. The walls of the orbit are made up of several bones: the frontal, lacrimal, zygomatic, temporal, sphenoid and palatine bones; the whole being lined by the periorbita (Lavach, 1990). The average dimensions of the orbit have been determined in the adult horse (Martin and Anderson, 1981), but not the foal. The orbital axes are directed forward and slightly upward, with an angle of approximately 160° between the two (Barnett and Bedford, 1985). Several foramina for vessels and/or nerves enter and exit the orbit.

The globe of the horse is an oblate spheroid in shape, the transverse dimension being the largest and the anterioposterior axis, the smallest (Lavach, 1990). It has been suggested that the unusual shape of the eyeball contributes to accomodation in this species (ramp retina), but this now seems unlikely (see Chapter 5). The normal dimensions, volume and weight of the globe of the adult horse have been recorded and reflect individual body size (Martin and Anderson, 1981). The extraocular muscles are within the orbit and attach to the globe. These are the dorsal, ventral, medial and lateral rectus, dorsal and ventral oblique, and retractor bulbi. Their insertions, sizes and innervation vary.

6.12 Congenital Conditions of the Eye and Orbit.

Anophthalmia.

This is defined as the congenital absence of an eyeball or any ocular tissue, and is rare (Slatter, 1981; Wilcock, 1983; Latimer and Wyman, 1985; Lavach, 1990). Most foals suspected of being anopthalmic are actually severely microphthalmic, in that dysplastic ocular remnants are found within the orbital fat and muscle. Ida Mann (1957) has cited 3 causes for the condition: 1) suppression of the optic analogue during optic plate differentiation; 2) secondary to complete suppression or anomalous development of the whole forebrain; 3) degenerative anophthalmia resulting from degeneration of the optic vesicle. Both unilateral and bilateral cases occur. The orbit is usually small, but otherwise well formed (Wilcock, 1983). The aetiology is rarely determined, but most cases seem to be sporadic and non-heritable.

Microphthalmia.

This refers to an abnormal smallness of the eye, which can be uni- or bilateral, and is one of the more commonly reported congenital ocular abnormalities in foals (Komar, 1964; Garner and Griffiths, 1969; Priester, 1972; Barnett, 1975; Koch *et al*, 1978; Dziezyc, Kern and Wolf, 1983; Mosier, Engelman and Confer *et al*, 1983; Latimer and Wyman, 1985; Roberts, 1992) (figure 40). Crowe and Swerczek (1985) revealed an incidence of 4.6% in 608 humanely destroyed foals and foetuses with lethal defects. The aetiology is unknown and many cases are sporadic and idiopathic. In others, obvious causes such as toxic, mechanical, infectious, or even nutritional insults, leading to degeneration or dysplasia of a partially formed optic vesicle (Munroe and Barnett, 1984; Latimer and Wyman, 1985). All cases are due to defective organogenesis and three classifications exist: 1) pure microphthalmia; 2) colobomatous microphthalmia; 3) complicated microphthalmia (Roberts, 1992). The severity of the microphthalmia depends on the gestational stage at which the insult occurs. The most severe forms are seen when the insult occurs early in gestation, at the time of optic vesicle and lens formation. All breeds are affected, but some such as the Thoroughbred have a higher incidence (Barnett, 1975; Munroe and Barnett, 1984). The role of inheritance has not been proven in the horse (Lavach, 1990).

The size of the globe varies considerably from a near normal structure with normal function (Latimer and Wyman, 1985), to a microscopic structure with only pigmented remnants (Garner and Griffiths, 1969; Dziezyc *et al*, 1983). Subtle micropthalmia, especially if unilateral, may require a full ophthalmological examination and corneal measurements before the defect can be confirmed. Even a 10% reduction in globe size results in severe visual deficits (Rebhun, 1991). Severe microphthalmia is more easily diagnosed due to the associated enophthalmos, blindness, and passive prolapse of the nictitans. The lid margins and aperture are reduced in size, the cornea and globe either not visible or abnormally pigmented, and the orbit smaller than normal (Wilcock, 1983; Munroe and Barnett, 1984; Rebhun, 1991). The poor nasolacrimal drainage and subsequent ocular discharge are associated with the abnormal anatomy of the globe, orbit and eyelid.

Secondary conjunctivitis is common due to environmental irritation and infection.

There is no treatment and bilaterally severely affected foals are usually destroyed. Unilateral cases can be used, will adapt, and can still make effective Thoroughbred racehorses in some cases. Enucleation of the affected globe may be necessary to prevent conjunctivitis, ocular discharge, and irritation due to fly attention (Munroe and Barnett, 1984; Rebhun, 1991). Microphthalmia can commonly occur as part of a complex of multiple ocular developmental abnormalities.

Multiple Abnormalities.

These abnormalities of one or both eyes, affecting several parts of the eye, occur sporadically in foals, possibly as often as pure microphthalmia (Rebhun, 1991). They appear most commonly in Standardbreds and Thoroughbreds. Any combination of lesion is possible including microphakia, corneal lesions, lens luxation, glaucoma, cataract, retinal detachment, colobomata, and microphthalmia (Trapp, 1957; Garner and Griffiths, 1969; Huston *et al*, 1977; Mosier *et al*, 1983; Dziezyc *et al*, 1983; Davidson, 1991; Rebhun, 1991; Williams and Barnett, 1993). Treatment is ineffective and the foal is blind in the affected eye(s). Enucleation may be necessary.

Buphthalmos and Glaucoma.

Glaucoma, an increase in intraocular pressure, can be classified into congenital (buphthalmos), primary (no antecedent eye disease), and secondary (following another eye condition, e.g. uveitis, lens luxation) (Barnett, Cottrell, Paterson and Ricketts, 1988).

Buphthalmos is rare in the horse and has been reported once in a Thoroughbred foal (Barnett *et al*, 1988). Priester (1972) and Huston *et al*, (1977) do not record it in their reviews of congenital ocular defects. In the recorded case, Barnett *et al* (1988) reported a unilaterally enlarged eye with elevated intraocular pressure, ciliary injection, fractures in Descemet's membrane, a dilated pupil unresponsive to light, corneal oedema and pain, congenital anterior and posterior synechiae, and scleral haemorrhages. A PM examination also found a lens coloboma, hypoplastic iris, and complete circumferential closure of the angle of filtration. This case was considered an associated bupthalmos, where the drainage angle is obstructed by a developmental abnormality elsewhere in the eye, in this instance of mesodermal structures of the eye.

Primary and secondary glaucoma are rare in the horse (Barnett *et al*, 1988) and have not been reported in the foal secondary to intraocular inflammation (Latimer and Wyman, 1985), although Whitley (1990) suggests that glaucoma secondary to uveitis should be considered where elevated intraocular pressure exists. Anatomical differences and a unique aqueous outflow facility may account for the low incidence of glaucoma. The authors experience is that severe intraocular damage usually leads to reduced pressure and phthisis bulbi in the horse .

Cyclopia.

Synophthalmia refers to a single eye in which some structures are paired and which is located in the middle of the forehead. Cyclopia refers to a single globe (no paired structures) similarly located (Slatter, 1981). Both conditions are rare but have been recorded in the foal (Van der Walt, 1935; Wilkens and Neurand, 1974; Crowe and Swerczek, 1985) From the description in the first two papers, the differentiation between the two conditions was not clear. Crowe and Swerczek (1985) describe 1 cyclopia and 4 synophthalmia. There is a failure of midline division of telencephalon, resulting in severe anomalous development of skull, brain and eye (Wilcock, 1983). Potential causes are myriad and seldom determined, but plant and selenium toxicity in sheep and inherited causes in the Guernsey/Jersey cow do exist (Wilcock, 1983).

Strabismus.

Strabismus is a deviation of the globe from the proper axis for a given species (Saunders, 1971). The abnormal position is attributable to excessive tension of certain of the extraocular muscles and/or excessive slackness of their opponents. The primary lesion is thought to be at the level of the cranial nerve nuclei. Strabismus is rare in the horse, but has been reported in mules at a frequency of 1 in 200 (Errington and Shipley, 1941, quoted in Blogg, 1985; Gelatt, 1982). The strabismus is usually convergent and asymmetrical in mules (Gelatt, 1982). The same author also reports convergent congenital strabismus in the horse. Lavach (1990) states that strabismus is more common in Appaloosas than other breeds.

Congenital hypertropia (dorsal deviation of the globe) has been reported bilaterally in two unrelated yearling Appaloosas with abnormal head carriage (Gelatt and McClure, 1979). This was corrected surgically. A dorsomedial strabismus has also been observed in Appaloosas seriously affected with equine night blindness (see Chapter 15) (Rebhun, Loew, Riis *et al*, 1984). Dorsal deviation of the nasal pupil also occurs in Appaloosas with, and without, equine night blindness (Latimer and Wyman, 1985).

Neonatal foals normally may have an eye rotated slightly inferionasally (ventromedial) with the horizontal axis of the palpebral fissure. By 1 month the globe turns slightly superiorly and nasally to the normal position for the adult (Lavach, 1990) (figures 41 & 85).

In neonatal foals with a strabismus, the only visible abnormality may be eye position, but affected foals usually have poor vision, assume abnormal postures or head tilting to improve vision, and can be difficult to examine (Lavach, 1990) .

6.13 Acquired Conditions of the Orbit and Globe in the Foal.

These conditons are rare in the neonatal foal, but do assume greater importance in the older foal and adult.

Trauma.

Blunt trauma to the orbit due to kicks or colliding with inanimate objects can lead to fractures of the surrounding bones. Physical examination for signs of facial asymmetry, crepitus, nasal discharge, and pain, plus radiography can be helpful in making a diagnosis (Davidson, 1991). Surgical intervention is required for depressed or comminuted fractures (Lavach, 1990).

Trauma to the globe occurs frequently, as the eye of the horse is large and prominent. It is prone to damage in the foal by kicks from mares or other foals, and from running into objects. Rupture of the globe is seen, with consequent loss of aqueous and collapse of the globe. Surgical repair is necessary as soon as possible to help to save the eye (Barnett and Bedford, 1985).

Phthisis Bulbi.

A small shrunken globe, is a common sequelae in the horse to severe ocular inflammation, including uveitis or trauma (figure 35). Collapse can be quite rapid and the resulting small globe may need to be removed if chronic conjunctivitis and discharge prove a problem (Davidson, 1991).

Herniation of Orbital Fat.

Herniation or prolapse of orbital fat is recorded in the foal, yearling and adult (Gelatt, 1970; Vestre and Steckel, 1983; Munroe and Belgrave, 1988). The orbital fat dissects a path anteriorly between the sclera and Tenon's Capsule to prolapse into the anterior episcleral space, usually between the nictitans and the globe. It may be caused by a congenital defect or trauma. There are no visual deficits and surgical closure of the defect has been recorded (Munroe and Belgrave, 1988) (figure 42).

6.2 RESULTS AND DISCUSSION.

The globe size, bilateral symmetry, and tone, as well as the presence/absence of strabismus and globe abnormalities were recorded in all 169 foals.

All the foals in this survey had two eyes with normal sized globes and orbits at first examination. Foal 73 did develop a severe phthisis bulbi of the right eye at 10 days old, after suffering with a uveitis secondary to a septicaemia (figure 35). Foal 119 appeared at first examination to have an enlarged orbit, but careful palpation revealed extensive eyelid oedema and swelling due to self-inflicted trauma, and a normal orbit and globe (figure 37). The intraocular pressure of all foals at first examination was normal.

All of the foals in this survey had a slight ventro-medial deviation, previously reported, in both eyes at the first examination (figure 85). This did not appear to vary within the 4 day neonatal period and confirms the findings of Adams and Mayhew (1985). No other type of strabismus was noted, other than that caused by the deep sedation of foal 113 when treated for NMS.

No other abnormalities of the orbit or globe were detected in this survey. In general terms the results of this survey suggest that congenital disease of the orbit and globe in the Thoroughbred foal is rare and confirms the similar opinion of Koch *et al* (1978). Even microphthalmia, which Barnett (1975) considered a regular congenital abnormality in the Thoroughbred, was not detected. However, accurate determination of the true incidence of these conditions would require a survey substantially larger than this one.

CHAPTER 7.

THE EYELIDS (excluding the Third Eyelid).

7.1 INTRODUCTION AND REVIEW OF LITERATURE.

7.11 Anatomy.

The eyelids of the horse are important for protection of the eye; tear film distribution, production and drainage; dislodgement of material from the corneal surface; and the cosmetic appearance of the head (Barnett and Bedford, 1985). Within their structure there are glandular components which contribute to the structure of the pre-corneal tear film, and blinking ensures that this fluid is adequately spread across the corneal surface. Blinking is the function of the orbicularis oculi muscle (figure 43).

The eyelids are composite structures, with a hair-covered external surface, and an inner surface lined by palpebral conjunctiva (figure 44). The two tissues join at the posterior edge of the eyelid margin. The upper eyelid in the adult is well supplied with cilia, or eyelashes, which are 3-4 rows of approximately 100 stiff modified hairs (Barnett and Bedford, 1985; Lavach, 1990). Lower cilia are usually absent or consist of a single row of fine, small short hairs (Wyman and Anderson, 1978). The foal has long and dense cilia superiorly, and rather sparse, short cilia inferiorly (occasionally absent) (Munroe and Barnett, 1984; Latimer and Wyman, 1985). Vibrissae, or tactile hairs, are present above and below the palpebral fissures. There are great individual variations in their number and length but, on average, there are 3 dorsal orbital vibrissae and 8 ventral (Lavach, 1990). Vibrissae are present below the eyes in all foals, and above the eyes in most (Munroe and Barnett, 1984; Latimer and Wyman, 1985).

The tarsal plate forms the internal skeleton of the eyelid and is composed of dense fibrous tissue with some elastic fibres. Its presence, along with corneal contact, helps maintain eyelid shape. Opening into the eyelid margin are the Meibomian glands: 30-50 modified sebaceous glands, which contribute to the tears (figures 55 & 56). The eyelid musculature has two components: one, the orbicularis oculi which is basically a sphincter muscle, contraction of which closes the palpebral aperture; the other, the levator superioris palpebrae which, when it constricts and the orbicularis oculi relaxes, leads to the aperture opening (Barnett and Bedford, 1985).

The palpebral conjunctiva is firmly attached to the eyelid and reflects onto the bulbar conjunctiva at the fornix. In both upper and lower fornices, accessory lacrimal glands open which, along with the goblet cells and glands in the palpebral conjunctiva, contribute to tear production. The lacrimal puncta are found just inside the eyelid (see Chapter 9). The medial canthus contains the hair-bearing caruncle, which is often pigmented (figures 49 & 61).

The dorsal and ventral orbital sulci are indentations, or creases, in the eyelids approximately 1cm. from, and parallel to, the eyelid margin in the adult horse (Wyman and Anderson, 1978). The palpebral fissure in the horse is not completely elliptical because the levator anguli oculi medialis inserts into the upper eyelid at the junction of the nasal third and the remainder of the eyelid (Lavach, 1990). The insertion causes a slight notching in the eyelid at this site. The length and width of the palpebral fissure are partially related to the size and position of the eye (Schmidt, 1984) (figure 45).

Blinking begins at the temporal canthus and proceeds nasally, propelling tears in this direction. Adult horses blink 25-125 times per 5 minutes with only 30% simultaneous bilateral blinking (Schmidt and Coulter, 1981). 3 ocular reflexes cause a blink. The first two, the palpebral and menace reflexes, have already been discussed. The corneal reflex, involves touching the cornea gently, and acheiving a blink via the ophthalmic branch of cranial nerve V, the trigeminal. This reflex was not used in this survey (figure 43).

7.12 Congenital Abnormalities of Eyelids in Foals.

Entropion.

Entropion is an inversion of the eyelid margin and eyelashes (Munroe and Barnett, 1984) and is the most common congenital eyelid defect in foals. Inversion can be congenital or primary, or acquired in early neonatal life (secondary) (Whitley, 1990). It may involve one or both eyes, and it only affects the lower lid (Lavach, 1990). The associated irritation may cause lacrimation, conjunctivitis, blepharospasm, photophobia, and corneal disease including keratitis, ulceration and perforation (Munroe and Barnett, 1984; Latimer and Wyman, 1985; Whitley, 1990). According to Barnett (1975), the condition is not uncommon in the Thoroughbred foal, and is both congenital and hereditary. Others (Peiffer, Williams and Schenk, 1977), believe that it is not hereditary but in neonates is probably related to such factors as, tone of the orbicularis oculi, tarsal plate weakness, and position of the globe. Munroe and Barnett (1984) suggest the condition is commonly seen in weak, premature, or systemically ill foals as a secondary problem due to enophthalmos. The latter forms part of the clinical picture of dehydration and anorexia which rapidly ensues in such cases. Painful conditions of the conjunctiva and cornea frequently lead to or exacerbate entropion due to the pain-associated blepharospasm (Roberts, 1992b). Early diagnosis of the condition, cause, and secondary complications such as corneal ulceration, is vital to achieve satisfactory results from treatment.

Treatment regimes vary enormously. Mild, early cases (first 12-24 hours) can be managed by gently everting the eyelid several times a day for up to 2 weeks, together with the application of a protective antibiotic ophthalmic ointment three times a day (Munroe and Barnett, 1984; Lavach, 1990; Whitley, 1990). Those cases that do not respond, or that are more severe, may be corrected by infiltrating procaine penicillin under the skin of the affected lid (Senk, 1983). This causes swelling of the lid and mechanical eversion. The swelling decreases during a 24-36 hour period and the procedure may need to be repeated. Temporary everting sutures using vertical or horizontal mattress sutures of nylon (Lavach, 1990), or surgical staples/vascular clips (Whitley, 1990), have been used, and need to be removed within 7-21 days. The skin will resume a normal texture in a few days. Overcorrection may stop the foal from blinking. Most cases respond to these treatments but severe, or unresponsive, congenital or acquired entropion may require surgical intervention. This is performed under general anaesthesia with careful assessment of the area and extent of incision to avoid overcorrection. A modified Hotz-Celsus procedure, where an elliptical portion of skin and muscle is removed, has been recommended (Peiffer *et al*, 1977; Gelatt, 1982; Munroe and Barnett, 1984). Other techniques are available (Lavach, 1990). The sutures are removed at 14 days and reassessment made at 6-8 weeks post-operatively.

Ectropion.

Ectropion, an eversion or turning out of the eyelid margin, occurs as both a congenital and acquired problem in the foal and horse. It is rare and only affects the lower eyelid. Roberts (1992b) reported 3 cases, two of which were due to trauma and one to overzealous surgical correction of an entropion. There is abnormal exposure of the palpebral and bulbar conjunctivae, and the cornea. Secondary inflammation of these structures may occur. Treatment consists of regular cleaning of the eye and ophthalmic ointments, or surgical correction (Munroe and Barnett, 1984).

Coloboma.

An eyelid coloboma is a full-thickness absence of lid structures that usually involves the lid margin, either uni- or bilaterally. The pathogenesis is unknown, although Roberts, (1992b) suggested that ischaemia to a rapidly developing embryonic eyelid may cause infarction of the lid farthest from the blood supply, thus resulting in a focal defect. The condition is rare (Latimer and Wyman, 1985; Whitley, 1990). They may accompany multiple congenital ocular abnormalities (Rebhun, 1991). Mild cases appear as a notch in the eyelid, whereas severe instances require reconstruction of the eyelid margin by blepharoplastic procedures.

Eyelid agenesis is a rare condition only reported once by Priester (1972). It was associated with multiple defects of the orbit and eye (Lavach, 1990).

Ankyloblepharon.

The lid margins of normal foals are separate, allowing the eyes to open at birth (Latimer and Wyman, 1985). Adhesion of the lid margins to eachother has been reported in a Shetland-cross foal as bilateral congenital ankyloblepharon (Fox and Thurman, 1969). In some foals it may indicate premature birth (Whitley, 1990). The lids can often be separated by minimal digital pressure shortly after birth. All other ocular structures usually appear normal. The nasal canthus is always open in ankyloblepharon in the foal, allowing an instrument to be introduced in the eyelid fissure to assist in opening the eyelids.

Dermoids.

Congenital dermoids are focal masses that resemble skin and can affect the eyelid margin, palpebral and bulbar conjunctivae, nictitans and, most commonly, the cornea. They will be described in later chapters.

Colour Dilution.

This is especially common in Appaloosa, Paint, Pinto and albino horses. It is very rare in Thoroughbreds. A portion, or the entire eyelid(s), may be devoid of pigment (Lavach, 1990). They are more sensitive to environmental irritation, especially by sunshine, and manifest this by blepharospasm, skin changes, loss of hair, conjunctivitis and ocular discharge.

7.13 Other Conditions of the Eyelids in Foals.

Blepharitis.

Blepharitis is an inflammation of the eyelid which can be caused by biting flies, bacterial infections usually secondary to lacerations, chemical irritants, and self inflicted trauma due to ocular irritation/pain (Latimer, 1987; Whitley, 1990). It may occur in the neonatal foal in association with contusions or abrasions of the eyelid occuring during convulsions/wanderings/blindness of NMS, or other severe neurological conditions such as bacterial encephalitis/meningitis. Both can also be caused by incorrect handling, prolonged lateral recumbency, or during periods in nursery paddocks where they sustain kicks or injure themselves. Actual lacerations of the eyelid are uncommon.

Distichiasis

This is a rare condition in the horse which is usually recorded in the adult only (Wilkinson, 1974). It can affect both upper and/or lower eyelid margins, and the cilia exit the meibomian glands which may be normally or abnormally positioned along the eyelid margin. These abnormal hairs contact the corneal surface, creating ocular irritation and direct corneal injury. Electroepilation is the most effective treatment. Districhiasis is the term used to describe two cilia growing from a single follicle and is rare in the horse.

Ectopic Cilia.

These are stiff hairs that originate at the base of the Meibomian gland, penetrate the palpebral conjunctiva and lie perpendicular to the corneal surface. They cause persistent or recurrent corneal ulceration (Miller, 1988), and are treated by *en bloc* excision of the cilia, or electroepilation. Most cases are in adults (Raphael, 1982).

Trichiasis.

Trichiasis, or abnormally directed normal lashes, is the most common cilia or hair related disease (Lavach, 1990) and occasionally appears in foals, although it is more common in older horses (Latimer and Wyman, 1985). It is related to upper eyelid laxity, and previous eyelid injuries, resulting in redirected eyelid margins (Rebhun, 1991). They cause lacrimation, blepharospasm and corneal ulceration. Either removal of the offending cilia and/or blepharoplastic procedures may be necessary to alleviate the problem.

7.2 RESULTS AND STATISTICS.

7.21 Basic Anatomy.

All 169 foals had complete upper and lower eyelids which were open immediately after birth (figure 46). Only 147 foals had the pattern of their cilia and vibrissae recorded.

Cilia (Eyelashes).

The results of the survey on the length and density of cilia in both upper and lower eyelids is shown in Table 7.1

	Length		Density	
Upper	Long	147	Dense	146
	Short	0	Sparse	1
	Nil	0	Nil	0
Lower	Long	0	Dense	1
	Short	143	Sparse	142
	Nil	4	Nil	4
Unrecorded		22		22

From these results the pattern of cilia in the vast majority of foals in this survey was:

Upper eyelid	Long and dense.
Lower Eyelid	Short and sparse.

In statistical analysis this combination was defined as NORM CILIA.

All recorded foals had long cilia in the upper eyelid, and 97% had short lower cilia (figures 47 & 48). 4 foals (<3%) had no lower cilia at all (figure 50). All foals, except one, had dense upper cilia and, again, all but 1 of those foals with lower cilia had a sparse cilia density (figures 47 & 49).

Vibrissae.

The results of the survey on the length and density of vibrissae in the upper and lower eyelids is shown in Table 7.2

		Length		Density
Upper	Long	144	0	2
	Short	1	1-5	144
	None	2	>5	1
Lower	Long	144	0	1
	Short	2	1-5	20
	None	1	6-10	126
Unrecorded		22		22

The usual pattern for vibrissae in foals in this survey was:

Upper eyelid	Long and density	1 - 5.
Lower eyelid	Long and density	6 - 10.

In statistical analysis this combination was called NORM VIBRIS.

Only two foals in the survey, that were recorded, had no vibrissae in the upper eyelid, and only 1 foal had none in the lower lid. The density was very clear in the upper eyelid but slightly more variable in the lower lid (figures 50 & 51). One foal (127) had 3-4 long grey hairs in the upper eyelid of its left eye which could have been confused with vibrissae.

7.22 Congenital Eyelid Abnormalities.

8 foals (5%) were identified as having eyelid abnormalities at the time of first examination in this survey. Table 7.3 details the findings in these foals.

KEY U = Upper L = Lower S/C = Subcutaneous
CMN = chloramphenicol

Foal	L	R	BIL	Lesion	Symptoms
16	L			Slight increased orbital sulcus	Normal foal. No eye abnormalities.
69			L	Severe secondary entropion. Conjunctivitis. No corneal damage.	Dysmature foal. S/C Propen. CMN eye ointment. 4 days to improve.
73			L	Secondary entropion (>R eye). No corneal damage.	Neonatal septicaemia. S/C Propen and manipulation. R eye uveitis phthisis bulbi.
111	L			Secondary entropion. Mild conjunctivitis.	NMS foal. 11hrs. post convulsions dehydration. Manual replacement. CMN eye ointment. 2 days to improve.
113			L	Mild entropion probably secondary. No ophthalmic abnormalities.	"Contracted Foal Syndrome". Category 5 foaling. Manual replacement of lids.
117			L	Primary entropion. Single manipulation. Orbital sulcus. L eye Retinal haemorrhages. No conjunctivitis.	Normal foal. Manual replacement. CMN eye ointment. Normal within 48 hours.

Foal	L	R	BIL	Lesion	Symptoms
119			UL	L eye severe blepharitis. Secondary entropion (lower) due to extreme enophthalmos. Severe conjunctivitis/chemosis. Traumatic Uveitis. R eye mild excoriation (lower)	Self-inflicted trauma in unattended foaling. ? NMS.
139		L		Excessive orbital sulcus. Eyelid edge flat to cornea.	Normal foal. No treatment. Normal in 48 hours.

Summary.

Entropion		
	Primary	1
	Secondary	5
	Total	6
Lower lid skin fold or increased orbital sulcus		3
Blepharitis		1

Entropion occured in 6 foals (3.5%), of which 5 had the secondary or acquired form. All those foals with secondary entropion had severe systemic problems, usually involving prolonged periods of intensive care, dehydration and collapse. One of these foals also had severe self-inflicted eyelid trauma. Statistically, there is a strong relationship in this survey between the incidence of lid abnormalities (especially entropion) and foal abnormalities. There was also a significant relationship between eyelid and conjunctival abnormalities, but not corneal. 2 of the foals had unilateral entropion, 4 were bilateral. All entropions were in lower lids.

3 foals had excessive lower lid skin folds, one of which was after a single eyelid manipulation for treatment of primary entropion (L eye). This condition was not associated with any ophthalmic or neonatal abnormality.

7.23 Other Conditions of the Eyelids.

The only other eyelid condition detected in this neonatal foal survey was a single case of mainly unilateral, self-inflicted, traumatic blepharitis, with lid oedema and abrasion in a NMS foal (figure 37). This was associated with a severe unilateral conjunctivitis, chemosis, uveitis, and blindness. The secondary entropion was unilateral (left) and in the lower lid, with the lid damage mainly upper in the left, and lower in the right.

7.3 DISCUSSION.

7.31 Anatomy.

This survey confirms that foals' eyes are open at birth (Whitley, 1990), or shortly thereafter (figure 46). The pattern of cilia distribution and appearance in the foals in this survey was very similar to that which has been previously recorded by Latimer and Wyman (1985) in foals, and Wyman and Anderson (1978), in adults. The normal appearance is of long and dense cilia in the upper eyelid and short, rather sparse cilia in the lower lid (figures 47, 48 & 49). Only 3% of foals in this survey were without lower cilia, which confirms the opinion of Latimer *et al* (1983); Latimer and Wyman (1985); and Munroe and Barnett (1984), but is in direct opposition to Lavach (1990), who states that they are usually absent in the lower eyelid (figure 50).

The normal pattern of vibrissae in the foals in this survey was long and between 1 and 5 in the upper eyelid (figures 47 & 51), and long and between 6 and 10 in the lower eyelid (figures 50 & 52). Only 2 foals had no vibrissae in the upper lid, and 1 foal none in the lower lid. The density was consistent in the upper eyelid but slightly more variable in the lower. These findings are entirely in agreement with the results of previous surveys (Wyman and Anderson, 1978; Latimer *et al*, 1983; Lavach, 1990) in both foals and adults, and there seems little difference between the generations.

In this survey, size, shape and appearance of the eyelids and palpebral fissure, in the foals with no abnormalities of the lids, were as expected from the previous surveys and literature (figures 47, 48, 49, 51, 52, 53, 54, 55, 57 & 58). There is little difference between the neonate and the adult in this area.

7.32 Abnormalities.

5% of neonatal foals in this survey had abnormalities of the eyelids, of which the majority had entropion (figures 34, 37, 50, 59 & 60). This is a much higher incidence than in either of the two previous surveys (Koch *et al*, 1978; Latimer *et al*, 1983). Koch *et al* (1978) reported 1 foal with a symblepharon as part of a multiple congenital eye abnormality, and Latimer *et al*, (1983) found a Thoroughbred foal that had had a treated entropion. Some of the differences in incidence may be related to populations and breeds examined, since Barnett (1975) stated that entropion was not uncommon in the Thoroughbred, and may even be hereditary or congenital. All the foals in this survey were Thoroughbred and neonatal in age group. This was not the case in the other surveys. It is possible that some foals had entropion at, or shortly after, birth in the above surveys which had corrected by the time of examination. The fact that this survey was random and was not biassed to examining "normal" foals may also have been a factor, because 5 of the 6 foals with entropion had the secondary, or acquired type, as a complication of systemic disease (figures 34 & 60). This confirms that most entropion in the neonate is secondary to dehydration or eyelid trauma in the compromised foal (Munroe and Barnett, 1984; Whitley, 1990) and, therefore, casts doubt on the hereditary nature of the problem in the Thoroughbred. All those foals with acquired entropion showed improvement in the eye problem as the systemic disease was treated and responded. All the entropions were in the lower lids, as previously recorded (Lavach, 1990; Whitley, 1990), with the majority bilateral. The bilateral cases were, in general, in those foals where dehydration and metabolic collapse were severe, whereas the unilateral cases possibly had more of a traumatic aetiology. The single primary case was bilateral (figure 59).

In general, entropion was associated in this survey with conjunctivitis, lacrimation, blepharospasm and mild photophobia (particularly in longer standing cases), but not major corneal disease. The usual corneal changes consisted of mild keratitis and oedema which rapidly resolved. It was not considered likely that any of the foals with entropion had developed it initially because of pain related to conjunctivitis or corneal pain (Latimer and Wyman, 1985), but it was clear that as these problems increased through eyelid irritation, a vicious cycle did develop. The possible exception to this rule was foal 119 where the entropion appeared secondary to severe eyelid abrasion and oedema, and intraocular pain (figure 37). Rapid and early diagnosis, and instigation of treatment was probably also responsible for the minimal corneal changes. All foals with entropion responded to either regular manipulation of the lid into a normal position every 2-3 hours, or the subcutaneous injection of procaine penicillin. This regimen alongside protective antibiotic ophthalmic ointments and intensive care was effective, within a few days, in all cases.

3 foals had increased lower lid skin folds (orbital sulci), one after a single manipulation to correct a primary entropion (figure 50). All 3 were in normal foals and self-corrected in 48 hours without treatment. They were not associated with any ocular abnormalities. This condition has not been reported previously. It may be a mild form of primary entropion which has not reached the stage of inverting the lid, or, which has self-corrected early in life. The author's opinion is that it

is a normal variation on the orbital sulcus pattern seen in all foals and adults. Transient changes in skin pliancy, body fluid balance, and muscle tone do occur in early neonatal life as a normal part of the adaptation from foetal to terrestial life, and in some foals this appears to be slower than normal. This leaves some foals with a skin that almost looks too large for the skeletal frame and lacks its natural elasticity. The affect on the lower eyelid is to leave excessive skin folds, probably because this lid moves much less than the upper (Wyman and Anderson, 1978), and the skin is slower to "tighten up".

No other congenital eyelid abnormalities were detected in this survey. The blepharitis, eyelid abrasion and oedema seen in the convulsing foal (119) (figure 37) is not uncommon in the Neonatal Maladjustment Syndrome (Rossdale and Ricketts, 1980; Brown, 1992). The severity of the problem in this foal was, however, exceptional as was the secondary uveitis. The entire left side of the foal (on which it must have been convulsing) was traumatised, especially over prominent parts of the head and body.

No abnormalities of cilia were detected in this survey. They are, however, rare and usually diagnosed in the adult.

CHAPTER 8.

CONJUNCTIVA AND THIRD EYELID.

8.1 INTRODUCTION AND REVIEW OF LITERATURE.

8.11 Anatomy of the Conjunctiva.

The conjunctiva is the mucous membrane which attaches the globe to the eyelids (Barnett and Bedford, 1985) and thus aids in the suspension of the globe within the orbit. The conjunctival tissue which covers the globe is the bulbar conjunctiva and, except where it blends into the limbus, is freely moveable to permit globe movement (Lavach, 1990). Near the limbus it becomes increasingly pigmented, especially temporally, although individual variation does occur (figures 62, 63, & 64). Some white, spotted, palomino, or chestnut horses have no bulbar pigmentation but the limbal zone is present in the majority of horses (Lavach, 1990). The palpebral conjuctiva is tightly adherent to, and forms the innermost layer of, the eyelids. The bulbar and palpebral conjunctivae meet at the fornix which is loosely folded to allow unrestricted ocular movement. Within the lower fornix is the third eyelid or membrana nictitans, and the caruncle, both of which are covered by conjunctivae (figures 49 & 61). The accessory lacrimal gland and the mucous-secreting goblet glands are found in the conjunctiva, and help form the precorneal tear film (Barnett and Bedford, 1985). Clusters of lymphoid cells are concentrated in the substantia propria of the conjunctiva around the limbus, along the bulbar surface of the nictitans, and in the inferior fornix.

The structure and appearance of the conjunctiva of the foal is not thought to differ in any way from the adult (Munroe and Barnett, 1984).

8.12 Congenital Abnormalities of the Conjunctiva.

Dermoids.

These are congenital masses of normal tissue growing in an abnormal site (Lavach, 1990). They usually contain elements of skin and can be uni- or bilateral. They can involve the conjunctiva, cornea or even eyelids, but in the horse the most common sites are the temporal cornea, conjunctiva and canthus (Barnett and Bedford, 1985). They are uncommon in the horse and are not thought to be heritable (Priester, 1972; Huston *et al*, 1983; Lavach, 1990). Conjunctival dermoids appear as fleshy, haired growths (short and stiff), pigmentation depending on the basic ocular pigmentation of the affected foal. The hairs cause ocular irritation, chronic conjunctivitis, epiphora, blepharospasm and keratitis (Rebhun, 1991).

Treatment involves wedge resection of the eyelid or conjunctiva and, in those extending into the cornea, keratectomy (Latimer, 1987).

Symblepharon.

An adhesion between two conjunctival sites, between cornea and a conjunctival tissue, or between the nictitans and another conjunctival tissue or cornea, constitutes a symblepharon. A case of congenital symblepharon with microphthalmos was mentioned by Koch *et al*, (1978). Often they are acquired due to surgery or injury of the conjunctiva.

8.13 Acquired Abnormalities of the Conjunctiva Affecting Foals.

Subconjunctival Haemorrhage.

Subconjunctival haemorrhage in foals is most commonly a result of rupture of local blood vessels during parturition (Latimer and Wyman, 1985; Whitley, 1990). As previously mentioned, it normally occurs under the bulbar conjunctiva overlying the sclera and, until recently, was called scleral haemorrhage. It is discussed in detail in the scleral chapter.

Conjunctivitis.

Conjunctivitis is the most common acquired ocular disease process in all species, including the horse, and because of its intimate relationship with the cornea and eyelids, either or both of these structures may be involved (Barnett and Bedford, 1985). There are many potential causes and both uni-/bilateral, and acute/chronic forms exist. In the foal, conjunctivitis can be either a primary problem or secondary to systemic disease. Primary conjunctivitis in the neonatal foal commonly results from irritation caused by foreign material such as bedding or food materials, or trauma, due to eyelid defects such as entropion, or directly during handling or convulsions (Latimer and Wyman, 1985; Whitley, 1990). Secondary bacterial infection may complicate the condition. Obstruction of the nasolacrimal system can be a cause or result of conjunctivitis. Clinical signs vary in degree according to the cause and stage of the problem, but include: blepharospasm, epiphora, hyperaemia, chemosis and, if bacterial infection exists, mucopurulent discharge. Treatment should include removal of the primary irritant and antibiotic ophthalmic ointment, the choice preferably being made on bacterial culture and sensitivity testing.

Secondary conjunctivitis can be caused directly by systemic bacterial or viral infections in any age foal, but most commonly in the older foal (1-6 months) (Whitley, 1990). It can also occur secondary to the effects of systemic infections, due to enophthalmos and resulting conjunctival irritation. Examples of systemic infections with secondary conjunctivitis include strangles (Streptococcus equi), foal pneumonias (Rhodococcus spp., Actinobacillus spp., and Adenovirus), and viral diseases such as equine viral arteritis, equine herpes virus and equine influenza. Diagnosis will require a thorough ocular and physical examination, with treatment directed at the major disease manifestations, both systemic and ocular.

Chemosis.

Chemosis, or oedema of the conjunctiva, occurs to some extent with any conjunctivitis. Following severe trauma to the eye, allergic reactions, or acute infections of the eye, extreme chemosis can occur and prevent lid closure. Treatment should be aimed at the determination and correction of the underlying cause (Latimer, 1987).

8.14 Anatomy of the Third Eyelid (Membrana Nictitans).

The membrana nictitans or third eyelid is a well developed and active structure in the foal and horse. It is composed of a T-shaped cartilage core, covered by conjunctival tissue and has a large number of lymphatic nodules present on its bulbar surface. A large seromucous gland surrounds the base of the cartilage shaft and contributes to the precorneal tear film. The whole structure is placed upon a large orbital fat pad. Movement of the third eyelid helps to remove foreign material and distribute the tear film, as well as physically protecting the cornea. Protrusion of the eyelid is caused by the action of the retractor bulbi muscle drawing the globe back into the orbit and causing the forward displacement of the orbital fat pad

The free margin of the nictitans is usually visible in the foal along the inferior nasal canthus, in close association with the cornea. The free margin is usually pigmented (Gelatt, 1982; Latimer *et al*, 1983) but in some animals it may be lacking, sometimes in association with absence of bulbar conjunctival and limbal pigment (Munroe and Barnett, 1984). This tends to make the third eyelid appear more prominent.

8.15 Congenital Conditions of the Third Eyelid (Membrana Nictitans).

These are rare and several have already been mentioned. Hypoplasia of the nictitans is usually seen as part of the microphthalmia complex (Munroe and Barnett, 1984). Symblepharon can affect the nictitans, usually limiting movement by adhesion to the bulbar conjunctiva. Gelatt (1982) thought that these occurred prenatally due to failure of separation between the two structures, or because of prenatal inflammation. Dermoids of the nictitans do occur rarely and have already been described (Rebhun, 1991).

8.16 Other Conditions of the Third Eyelid (Membrana Nictitans) in the Foal.

The membrana nictitans will be involved in any type of conjunctivitis already mentioned, with chronic problems leading to the eyelids' lymphoid follicles becoming hyperplastic and remaining after the initiating cause is corrected.

Protrusion of the eyelid will occur unilaterally as a result of an orbital mass, ocular pain, a shrunken globe (microphthalmos or phthisis bulbi), or Horner's syndrome. Bilateral protrusion may be due to systemic disease, such as tetanus.

8.2 RESULTS AND STATISTICS.

8.21 Anatomy of the Conjunctiva.

The results of this survey confirmed that the conjunctivae of the neonatal foal do not differ morphologically in any way from the adult horse. Variation did occur in the degree and extent of conjunctival pigmentation and appeared to relate partially to coat colour, and colouration of the nictitans. Pigmentation was generally less in chestnut foals than bay or grey, but concentration at the limbus was very common (figures 62, 63, 64, & 65).

8.22 Congenital Abnormalities of the Conjunctiva.

None of the foals in this survey had any congenital abnormality of the conjunctiva.

8.23 Acquired Abnormalities of the Conjunctiva in the Neonatal Foal.

The incidence and type of conjunctival abnormalities found in this survey are shown in Table 8.1

Foal	L	R	BIL	Lesion
63		*		Conjunctival inflammation/hyperaemia. MP discharge. Trauma (see nictitans).
69			*	Conjunctivitis with bilateral 2°y entropion.
73			*	Conjunctivitis with profuse SM discharge. Bilateral 2°y entropion.
99			*	Subconjunctival haemorrhages.
103			*	Subconjunctival haemorrhages.
104			*	Subconjunctival haemorrhages.

Foal	L	R	BIL	Lesion
106			*	Subconjunctival haemorrhages.
111	*			Mild conjunctivitis. 2°y L eye entropion.
119			*	L eye severe chemosis/conjunctivitis related to self-inflicted trauma to head/body. MP discharge. Subconjunctival haemorrhage. R eye as above but milder.
120	*			Subconjunctival haemorrhage.
121		*		Mild subconjunctival haemorrhage.
122			*	Subconjunctival haemorrhage.
123			*	Subconjunctival haemorrhage.
124	*			Subconjunctival haemorrhage.
128		*		Subconjunctival haemorrhage.
133	*			Mild subconjunctival haemorrhage.
151		*		Subconjunctival haemorrhage.
157			*	Mild conjunctivitis and vessel injection associated congenital corneal pannus.
161			*	R eye mild conjunctivitis and vessel injection. L eye subconjunctival haemorrhage.

KEY

MP = mucopurulent 2°y = Secondary

SM = seromucoid L = Left

R = Right

19 foals (11%) had conjunctival abnormalities. These break down into three main groups shown in Table 8.2

	L	R	BIL
Conjunctivitis secondary to entropion	1		2
Other causes of conjunctivitis:			
Unknown	0	1+	0
Trauma	0	1	1*
Congenital corneal pannus	0	0	1
Subconjunctival haemorrhage	5+*	3	6

3 foals had conjunctivitis secondary to entropion (figure 34). 4 foals had conjunctivitis due to other causes: 2 trauma, 1 in association with congenital corneal pannus, and the other of unknown aetiology (figures 38, 66 & 67). Bulbar subconjunctival haemorrhages occurred in 14 foals: 6 bilaterally, 3 in the right eye and 5 in the left. 2 of the left eye subconjunctival haemorrhages occurred with conjunctivitis (+ *)(figure 68). No other abnormalities were recorded.

Abnormalities of the left and/or right conjunctiva showed a statistically significant relationship with eyelid abnormalities including the nictitans, foaling category (especially 3) and scleral abnormalities. Links with foal abnormal behaviour and corneal opacity did exist but the significance was questionable because of the low expected values on the Chisquare test (small number of foals involved). There was no relationship between conjunctival abnormalities and: cilia size and density; pupillary light and menace reflexes; and foal size.

8.24 Anatomy of the Membrana Nictitans.

All foals had a nictitans in each eye at the time of first examination. All were of normal size except the one nictitans in the single foal with an abnormality.

The pigmentation of the third eyelids in this survey are shown in Table 8.3

1. Whole-coloured pink	42
2. Pink, black edge	125
3. Other	2

All foals had bilaterally symmetrical pigmentation of the nictitans except 1 foal in group 3, which had the left eye in group 2, and the right in group 1 (figures 69 & 70). 42 foals had whole-coloured pink nictitans with no black pigmentation (figures 58 & 62), whereas 125 had a pink nictitans with varying amounts of black pigmentation, particularly concentrated at the leading edge (figures 61, 71 & 72). 1 foal in group 3 had a red nictitans.

There was a very strong statistical relationship between nictitans colouring and the foal coat colour. Group 1, the whole-coloured pink was almost exclusively in chestnut foals, whereas group 2, pink with black edge, was mainly in bay, grey, or bay-brown foals.

8.25 Congenital Abnormalities of the Membrana Nictitans.

No congenital abnormalities of the third eyelid were found in this survey.

8.26 Other Conditions of the Membrana Nictitans.

Only one third eyelid abnormality (0.5%) was recorded in this survey. Foal 63 had a right nictitans swollen and oedematous on the palpebral surface, associated with a congested, inflamed right conjunctiva and mucopurulent ocular discharge (figure 60). The left eye was normal.

8.3 DISCUSSION.

8.31 Conjunctiva.

The appearance of the conjunctiva in the neonatal foal does not differ significantly from that seen in the adult horse according to the results of this survey, and confirms previous work (Munroe and Barnett, 1984). Pigmentation differences between foals in this survey partially correlate with coat colour and nictitans colour (figures 62, 75, 76, 77 & 113). Chestnut foals in this survey had a higher incidence of lack of, or decreased, bulbar conjunctival pigmentation, than bay foals. This related to the whole-coloured pink nictitans category seen in chestnut foals (see later) (figures 58 & 62). Concentration of pigmentation at the limbus was confirmed (Lavach, 1990)(figures 64, 65, 73 & 74). Lack of bulbar pigmentation in the foal tended to concentrate one's attention on the eye and superficially suggested a microcornea (figure 62).

No congenital abnormalities of the conjunctivae were detected in this survey, confirming their very low incidence (Priester, 1972; Huston *et al*, 1977; Munroe and Barnett, 1984).

Acquired conjunctival abnormalities were found in 11% of foals in this survey. 14 of these foals had subconjunctival haemorrhages (bulbar) which will be discussed in the sclera chapter. The rest of the foals in the acquired group had conjunctivitis (5) (figures 34, 38, 66 & 67), and 2 of those with subconjunctival haemorrhages also had conjunctivitis. One of the group with conjunctivitis, in which trauma was the cause, also had a severe chemosis. Conjunctivitis is the most commonly acquired ocular disease in the horse but there are no reports on its incidence in the foal. Koch *et al* (1978) had no cases recorded in 82 foals, whereas Latimer *et al* (1983) recorded 2 foals with unilateral purulent discharge and conjunctivitis in 144 foals. The majority of foals in the two surveys were older than the neonatal foals in this study, and it is possible that problems that may have been present in some of these foals as neonates would have disappeared by the time of examination. All the causes of conjunctivitis in this survey occurred before, at, or shortly after parturition, and the clinical signs were recognised early in the foal's life. This allowed for early treatment . There was no bias to either eye and uni- and bilateral cases occurred equally frequently. Most of the cases of conjunctivitis were primary, due either to irritation by an entropion or direct birth/early neonatal trauma. One may have been caused by intra-uterine irritation (figure 78) (see chapter 10). These results confirm previous statements on neonatal foal conjunctivitis (Whitley, 1990). The three most severe cases developed a more profuse mucopurulent/seromucoid ocular discharge and may have been complicated by secondary bacterial infection (figure 60). None of the foals appeared to have a secondary conjunctivitis caused by a systemic infection, probably because most of the causes of this problem occur in older foals.

Severe, acute, unilateral chemosis occurred in one NMS foal which had suffered extreme self-inflicted trauma to the eye. Besides the chemosis, the accompanying conjunctivitis was the most severe seen in this survey (figure 38).

In general, the incidence of abnormalities of the conjunctiva appeared to be related to lid and nictitans abnormalities. The connection between both conjunctival and lid abnormalities, and corneal opacification was not proven because of limited numbers, although a trend did exist. These results reflect the inter-dependency of these structures on eachother for their health and effective function.

8.34 Membrana Nictitans.

The nictitans was of normal size and shape in all of the foals in this survey, except one right eye. Pigmentation of the leading margin was confirmed in 74% of foals (figure 77), and was statistically related to bay, grey and bay brown coat colours. Pigmentation of the nictitans was also related to the overall bulbar conjunctival pigmentation. 25% of foals had non-pigmented margins, with a very strong relationship between this and chestnut coat colour (figure 58). In all cases, except 1 foal, the pigmentation was bilaterally symmetrical (figures 69 & 70). These findings tend to agree with Gelatt (1982) and Latimer *et al*, (1983), but differ in the higher numbers of non-pigmented margins and their bilateral symmetry. The differences may be because of the mixed population of breeds in the Latimer *et al* (1983) survey, some of which have less chestnut coat colour in them than modern U.K. Thoroughbreds.

There was a very low incidence of abnormalities of the nictitans in this survey. No congenital abnormalities were found. The conjunctivitis already discussed did obviously, to some degree, affect the conjunctival surfaces of the nictitans. The acquired third eyelid abnormality was thought to be due to trauma during attempts by the foal to stand. A left hind flexor deformity did lead to difficulties and delays in rising. Further trauma may also have occurred due to a period of colic related to retained meconium.

CHAPTER 9.

NASOLACRIMAL SYSTEM.

9.1 INTRODUCTION AND REVIEW OF LITERATURE.

9.11 Anatomy.

The largest part of the production of equine tears is derived from the lacrimal gland, which is located in the dorsolateral periorbital tissues and opens by 12-16 excretory ducts into the superior lateral fornix (Peiffer, 1979). Together with the nictitans gland, it produces the aqueous middle layer of the precorneal tear film, the outer lipid layer being produced by the Meibomian glands. The inner mucoid layer is derived from the conjunctival goblet cells (Barnett and Bedford, 1985). The precorneal tear film serves to flush foreign body material from the corneal and conjunctival surfaces; ease eyelid movement by lubrication; smooth the corneal surface to improve optical efficiency; and help in corneal nutrition.

Some 25% of the precorneal tear film is lost by evaporation, and the rest is drained into the nasal cavity by the nasolacrimal system. This consists of two lacrimal puncta, one on each eyelid margin (nasocanthal), that connect together at a poorly formed nasolacrimal sac. The nasolacrimal duct passes from the sac downwards through the maxillary bone to emerge, by a slit-like or oval opening of variable size, at the mucocutaneous junction on the nasal floor near the nostril (Munroe and Barnett, 1984).

Lavach (1990) has defined lacrimation, or the increased production of tears, as a response to a stimulus such as ocular pain, or infections/inflammations of the mucosal surfaces or lacrimal glands. Epiphora, the overflow of tears, is a result of interference with normal tear drainage. This can be caused by a congenital abnormality or acquired obstruction to normal flow through the lacrimal puncta, canaliculi, sac, or duct, or any abnormality of the eyelid margin that allows tears to spill over the eyelid (Harling, 1988). Examination of the nasolacrimal system can include a visual inspection for puncta and epiphora (Harling, 1988), flushing of the eyelid or nasal puncta (Lavach, 1990), passage of a catheter, or dacryocystorhinography (Latimer, Wyman, Diesem and Burt, 1984). Only visual inspection was carried out in this survey.

9.12 Congenital Abnormalities of the Nasolacrimal System.

Congenital blockage of this system can occur at various points, including eyelid punctum atresia and ectopic eyelid puncta, but is less common than the acquired forms. Congenital impatency of the nasolacrimal duct can be anywhere along its length, but atresia of the nasolacrimal meatus puncta is most common (Latimer and Wyman, 1984; Roberts, 1992b). None of the conditions are thought to be inherited. Lesions may be uni- or bilateral.

In atresia of the nasal punctum, the opening, and often a variable length of nasolacrimal duct, will be missing (Hjorth, 1971; Lundvall and Carter, 1971; Mason, 1979; Latimer and Wyman, 1984; Lavach, 1990). There is usually epiphora, sometimes delayed in onset or unnoticed (due to watery nature) for 3-4 months, and often mucopurulent ocular discharge due to a secondary dacryocystitis (Latimer and Wyman, 1984). Palpation of the nasal vestibule may reveal a distended fluctuating structure (Lundvall and Carter, 1971; Mason, 1979). Treatment involves creating a new nasal punctum by incising the mucosa through the nostril or wall of the nose. Tubing is left in place to prevent the new opening sealing (Lavach, 1990).

Atresia can also occur at the eyelid puncta but is uncommon. It may affect one or both puncta, with the foal developing epiphora within the first 6 weeks of life, in most cases. Establishment, or enlargement, of the puncta surgically is usually efffective (Lavach, 1990). Misplaced puncta on their own, and not part of a generalised abnormality, are uncommon as a cause of epiphora. 2 foals with epiphora have been recorded with a single punctum located nasally and further from the eyelid margin than normal. Enlargement of the puncta lead to improvement (Lavach, 1990). Other problems include multiple openings of the nasal punctum, and dermoids of the eyelids and nictitans affecting the puncta.

9.13 Acquired Abnormalities of the Nasolacrimal System Affecting Foals.

Dacryocystitis can be uni- or bilateral and may be caused by a foreign body in the nasolacrimal system, parasites, a dusty environment, respiratory infections, neoplasia, trauma, or chronic conjunctivitis. Clinical signs include nasolacrimal obstruction, mucopurulent ocular discharge, conjunctivitis and possibly head rubbing (Whitley, 1990; Davidson, 1991). Treatment should include saline and antibiotic flushing, intermittently or daily via an indwelling catheter.

Tear production in normal, full-term, neonatal foals is usually adequate, but premature foals, foals with Neonatal Maladjustment Syndrome, and foals with facial nerve paralysis may have subnormal tear production (Whitley, 1990). Evaluation of the eye by pen torch and the Schirmer tear test (figure 79), may be helpful in reaching a diagnosis. Treatment with artificial tear products is usually adequate. Secondary bacterial conjunctivitis may require the use of topical antibiotic preparations. Keratoconjunctivitis sicca has not been reported in the young foal.

9.2 RESULTS AND DISCUSSION.

No abnormalities of the nasolacrimal system were detected in this survey. The reason for this, besides the fairly uncommon occurence of these conditions, especially the congenital ones, is that the foals were all young. Senk (1983), Latimer and Wyman (1984), Lavach (1990), and Rebhun (1991) all state that epiphora in congenital anomalies of the nasolacrimal system is usually not noticed until 2-8 weeks after birth, and in some foals may be as late as 4-6 months. This also confirms the author's own experience in that the 4 cases of this condition he has seen in the Thoroughbred have all been recorded in yearlings. Hjorth (1971), Mason (1979), and Latimer and Wyman (1984) all recorded cases, regarded as congenital, in yearling horses of different breeds. Although Rebhun (1991) was unaware of any reason for this delay, Riis (1981) and Roberts, (1992b) suggested that it may be due to a lower tear-secreting ability in neonates and young foals. Dilation of the nasolacrimal duct allowing retention of a larger volume of tears (Lavach, 1990), and transmucosal absorption of tears through the lining of the duct (Latimer *et al*, 1984), are other alternative or additional explanations. Confusion with the epiphora of conjunctivitis is possible (figure 34), although the severity and type of ocular discharge present would be inconsistent with the mild conjunctivitis seen in nasolacrimal obstruction (Latimer and Wyman, 1984).

Dacryocystitis is also very unusual in young foals (Senk, 1983) and was not recorded in this survey. The problems of depressed tear production in systemically ill foals was noted in so affected animals in this survey. A standard protocol of four times daily careful cleaning of the eyelids and insertion of an artificial tear/antibiotic ophthalmic solution was followed in all these cases, particularly in view of the high rate of secondary entropion often present or ensuing.

CHAPTER 10.

THE CORNEA.

10.1 INTRODUCTION AND REVIEW OF LITERATURE.

10.11 Anatomy.

The cornea is the transparent anterior continuation of the sclera and it occupies approximately one quarter of the total amount of exposed corneal and conjunctival surface (Riis, 1981). The normal cornea in the neonate is clear, roughly oval in shape, broader nasally and has a smaller radius of curvature than the sclera. The average corneal dimensions for older foals (3 different breeds) were recorded, and that for the Thoroughbred was 25.7mm in the horizontal plane and 19.5mm in the vertical plane (Latimer *et al*, 1983). This was some 6.8mm less in each direction when compared to the adult (Martin and Anderson, 1981).

The cornea is thinnest axially and thickest peripherally. The scleral shelf, or overhang, is more prominent dorsally and ventrally, preventing visualisation of the iridocorneal angle structures in these areas (Latimer *et al*, 1983; Lavach, 1990). However, these structures are often visible at the nasal and temporal limbus as a "grey line", representing the insertions of the pectinate ligaments into the cornea at the termination of Descemet's membrane (Latimer *et al*, 1983; Munroe and Barnett, 1984; Moore, 1987; Lavach , 1990).

The cornea is composed of a non-keratinised stratified squamous epithelium with its basement membrane, the corneal stroma, the endothelial basement membrane (Descemet's membrane), and a monolayer of endothelial cells (figure 80 & 81). The epithelium provides an effective superficial barrier to microbes, excessive fluid entry, and particulate matter. It contains many free nerve endings (ophthalmic branch Trigeminal V). The stroma accounts for over 90% of the total corneal thickness and consists of a precise, orderly arrangement of stromal cells and collagen lamellae. Its optical function depends on its compactness and dehydrated state. The endothelium (single layer) and the elastic Descemet's membrane serve as an inner barrier. The stroma is kept in its relatively dehydrated state by the regulation of fluid content by the epithelium and endothelium active fluid pump. Damage to either tissue results in fluid being absorbed directly by the stroma, and the resulting lamellar distortion renders the cornea opaque. As the cornea is avascular, it is nourished by the tears externally and the limbal vessels and aqueous humour internally (Barnett and Bedford, 1985; Moore, 1987; Lavach, 1990).

10.12 Congenital Diseases of the Cornea.

Abnormalities affecting the cornea of neonatal foals are rare (Priester, 1972; Gwin, 1983; Lavach, 1990).

Dermoids.

These are the most common congenital abnormality of the equine cornea and are choristomas, or congenital mislocation of normal tissue (McLaughlin and Brightman, 1983; Moore, 1987). They are not thought to be inherited, can be uni- or bilateral, and have already been mentioned in Chapters 7 and 8. Corneal dermoids commonly involve the lateral aspect of the cornea especially the limbal junction, although any part of, or the entire, cornea can be affected. They contain hair follicles, sebaceous glands, and other dermal structures. Depending upon the size, location and presence of hairs, dermoids can cause corneal and/or conjunctival irritation or visual disturbance (Gwin, 1983; Latimer and Wyman, 1985; Moore, 1987; Lavach, 1990). The clinical characteristics of the dermoid, and the presence or absence of other ocular abnormalities, will dictate whether surgical excision is necessary or feasible.

Two slightly different types of dermoids have been observed in the foal (Moore, 1987). One form, with a thick localised tissue mass and distinct tuft of hair, is usually well differentiated, superficial, and can be excised by superficial keratectomy. A less common form may be associated with multiple ocular abnormalities such as microcornea, persistent pupillary membranes, and anterior segment cleavage problems. It is often flattened, poorly differentiated, intensely pigmented and, in general, surgical excision is not recommended. Some cases may extend to all corneal layers and be associated with anterior segment malformations such as vascular channels from the iris (Saunders and Rubin, 1975).

Microcornea.

This usually occurs in conjunction with the microphthalmia complex or multiple ocular defects (Gelatt, 1982; Latimer and Wyman, 1985; Rebhun, 1991), although it has been noted as the only abnormal finding in a visual eye of normal size (Munroe and Barnett, 1984). Foals that lack perilimbal conjunctival pigment may give the impression of microcornea because of the prominent sclera (figure 62).

Megalocornea.

This has been reported in multiple congenital ocular abnormalities and also, unilaterally, in normal foals with normal globes and intraocular pressures within normal limits (Latimer and Wyman, 1985).

Corneal Melanosis.

An anterior corneal melanosis involving the epithelium and superficial stroma of the central cornea has been described in the foal (Gelatt, 1982; Latimer and Wyman, 1985; Moore, 1987). Corneal neovascularisation may be a component of this congenital opacity. It has also been observed with corneal dermoids and persistent pupillary membranes (Munroe and Barnett, 1984). It is not painful or progressive. Removal by superficial keratectomy is often successful, but other intraocular abnormalities should be checked for first (Whitley, 1990).

Persistent Pupillary Membrane (PPM).

Focal corneal opacities associated with PPM's will result when they attach to the corneal endothelium (Moore, 1987; Lavach, 1990; Whitley, 1990). PPM's represent strands of persisting mesodermal tissue (the anterior tunica vasculosa lentis) that arise from the anterior iridial surface (figure 82). They will be discussed more fully in Chapter 12. Treatment is not usually indicated since improvement occurs with time and vision, in all but the most severe cases, is not affected (Gwin, 1983).

Corneal Opacity.

Opaque or partially opaque corneas are aften associated with microphthalmia and multiple ocular deformities in foals (Lavach, 1990). Latimer *et al* (1983) described irregular punctate corneal opacities in 5 of 9 Thoroughbred foals on one stud. They were uni- and bilateral, limited to the epithelial layer, and resolved spontaneously over a 5 month period.

Thin vertical band and linear opacities have been seen in foals (Gelatt, 1982; Walde, 1983a). These involve the deep stroma, or a histologically abnormal Descemet's membrane, are not progressive and not associated with inflammatory sequelae (Moore, 1987; Whitley, 1990). No treatment is available or indicated. Their aetiology is unknown.

A congenital corneal staphyloma in a foal was reported by Müller (1942) cited in Lavach (1990).

10.13 Acquired Diseases of the Cornea Affecting the Foal.

Ulceration.

The foal, because of its lack of handling and relative inexperience, and its rather susceptible exposed eye, is predisposed to corneal trauma (Gelatt, 1982). Corneal ulceration is commonly caused by trauma, but other causes in the foal include: entropion, foreign bodies, dermoids, ectopic cilia or distichiasis and, in the systemically ill or comatose foal, by lack of blinking and suppressed tear production (Whitley, 1990). In the neonatal foal most ulceration is superficial, which means loss of corneal epithelium and basement membrane (Moore, 1987). These acute ulcers are painful, the foal exhibiting blepharospasm and lacrimation (Gwin, 1983). Secondary bacterial, or occasionally fungal, infection can develop leading to purulent ocular discharge. Bacterial culture, corneal cytology and fluorescein testing are useful in diagnosis (figures 6 & 7). Treatment of superficial ulcers involves topical antibiotic preparations four times daily, with atropine 1% if the pupil is miotic or the eye very painful (Whitley, 1990). If the ulceration becomes chronic, then debridement of undermined epithelial edges with a 1% pevidine iodine swab and scalpel blade may be necessary (Severin, 1976). Third eyelid flaps, or temporary tarsorrhaphy, and subpalpebral lavage systems can be used in large chronic or infected ulcers (figure 83).

If the ulceration is deep, with the loss of stromal tissue as well, there will be superficial vascularisation, corneal oedema, possibly hypopyon and, surprisingly, less apparent pain (Gelatt, 1982; Lavach, 1990). It is very unusual for an ulcer to develop this far in the neonate but possible complications include secondary uveitis, descemetocoele, corneal abscesses, endophthalmitis and loss of the eye (Whitley, 1990).

Ulcers caused by Equine Herpesvirus I (EHV 1) can occur in foals and appear as punctate ulcers or multiple punctate white corneal lesions. Viral isolation can be attempted from corneal samples, but other diagnostic avenues are more productive. Topical antibiotic and antiviral preparations may be beneficial (Matthews and Handscombe, 1983a).

Corneal Lacerations.

Corneal lacerations are not uncommon in foals, but usually those older than neonates (Gelatt, 1982; Barnett and Bedford, 1985; Moore, 1987). Surgical repair under general anaesthesia is possible (Whitley and Turner, 1986; Blogg, 1987) (figure 84).

10.2 RESULTS AND STATISTICS.

10.21 Anatomy.

Size and Shape.

No abnormalities of corneal size or shape were recorded. The normal cornea in this survey was clear, oval in shape, and wider on the nasal canthus side (figures 62 & 85). The corneal dimensions were not measured. There were minor variations in corneal size and shape noticed during this survey but these were not considered significant enough to record.

Pectinate Ligament.

The presence and position of the "grey lines" representing the insertions of the pectinate ligament into the cornea, are recorded in Table 10.1

No. of foals in which the presence or absence of the scleral shelf and pectinate ligament insertions was recorded:

103

No. of foals in which the presence or absence of the scleral shelf and pectinate ligament insertions was unrecorded:

66

Pectinate ligament insertions		**% of recorded**
Temporal/nasal	63	62
Temporal/nasal + dorsal	1	<1
Not present	39	37

Scleral Shelf.

The presence of a scleral shelf was recorded in Table 10.2

Scleral shelf			% of recorded
	Dorsal and Ventral	64	62
	Circumferential	5	4
	Not present	34	33

Statistically there was a strong correlation between the incidence of a dorsal/ventral scleral shelf (figures 55 & 87) and temporal/nasal pectinate ligaments (figures 53, 58, 72 & 86). 5 foals were recorded with a circumferential scleral shelf and no pectinate ligaments visible. 1 foal was recorded with almost circumferential pectinate ligaments and no scleral shelf (figure 63). The actual incidence of both entities is likely to have been underestimated in this survey because of the high numbers of unrecorded foals in this section.

The relationship of a combination of scleral shelf (dorsal/ventral) and pectinate ligament (temporal nasal) with a number of other parameters in the survey was investigated. There is no relationship statistically with foal colour, vision, pupillary light reflexes, nictitans colour, or iris abnormalities. It does, however, have a strong correlaton with iris colour and appearance. There is an overrepresentation of grey-brown, grey, and light brown iris colour, and iridescent iris appearance in the combined scleral shelf/pectinate ligament group.

10.22 Congenital Abnormalities of the Cornea.

5 corneal abnormalities were recorded in this survey of which 1 (<1%) had a congenital abnormality. Foal 157 had a bilateral, dorsal, limbal vascularisation (figures 63, 66, 73, 78, 88 & 89). The right eye was more severely affected with approximately 3mm. in length, short, straight corneal vessels present along the whole length of the dorsal limbal region of the cornea (figure 66). The left eye had three discrete areas of similar, but less obvious, vessels again along the dorsal limbal region of the cornea (figure 78). The foal was normal, with no abnormal gestational or parturition history. It was examined initially at 16 hours after birth, at which time the only ocular abnormality, other than previously described, was a mild bilateral conjunctivitis and scleral vessel injection. There was no evidence of corneal oedema, ulceration, ocular pain or discharge (figures 66 & 78). The foal was re-examined at 40 and 88 hours after birth. At 40 hours post-partum, the corneal vascularisation in both eyes had considerably decreased in a centripetal direction from the limbus. The mild conjunctivitis had gone (figures 63 & 73). The vascularisation at 88 hours post partum was further resolving, such that in the right eye there was a decrease in numbers and size of the vessels, and a clear corneal gap of 3-4mms between the islands of vessels and the limbus (figure 88). The left eye had a similar direction and degree of resolution. The vascularisation had disappeared at 7 days post-partum. At no stage was any treatment given.

10.23 Acquired Conditions of the Cornea.

Of the 5 abnormalities of the cornea recorded in this survey, 4 (2%) were considered to have been acquired. They are recorded below.

70 A bilateral foreign body, consisting of strands of hair wound round into a tight ring, present on the front of both corneas at 14-16 hours post-partum (figures 90 & 92). Mild corneal oedema and ulceration was visible after the foreign body was removed from the right eye. There was also early, perilimbal, neovascularisation in the right eye (figure 91). No corneal changes were seen in the left eye. Other than mild lacrimation there appeared to be no evidence of ocular pain in either eye. The foal was dull, undersized and slow to stand and suck. The foaling was unattended and the mare was in poor condition with an abnormal gestational history. Treatment of the right eye with antibiotic ophthalmic ointment three times daily resolved the ulceration in 7 days.

73 Mild corneal oedema, right worse than left, with no evidence of ulceration. Bilateral secondary entropion. The foal had a neonatal septicaemia. The left eye gradually resolved as the entropion was corrected. The right eye, which had the more severe entropion, also developed an acute septic uveitis with hypopyon at 5 days post-partum. This was accompanied by a ventral, deep corneal vascularisation, and further mild oedema. There was gradual reduction in intraocular pressure, with a worsening entropion, pannus and oedema. The foal was euthanased as a result of other problems (figures 34 & 35).

111 Mild desiccation and keratitis, with a secondary bilateral entropion, in a foal with NMS. All these resolved with treatment and systemic recovery of the foal.

119 A NMS foal with severe, bilateral, self-inflicted ocular trauma which was worse in the left eye. Left eye was photophobic, had severe ocular pain with blepharospasm, lacrimation and acute uveitis. There was a mild corneal oedema and a diffuse keratitis (fluorescein uptake) (figure 38). The right eye had less severe ocular abnormalities, with mild corneal oedema and no fluorescein uptake.

In total, of the 5 corneal abnormalities detected in this survey, 3 were related to trauma (2 entropion, 1 self-inflicted), 1 was a foreign body, and the other a spontaneously resolving congenital abnormality.

Statistical analysis was carried out on the foals with corneal opacity or abnormality, but the small numbers involved means that the results should not be overinterpreted. There was an increased incidence of lack of vision, abnormalities of the eyelids and, possibly, lack of pupillary light response, in the abnormal cornea group. There was no correlation with menace response, third eyelid abnormalities, or cilia conformation.

10.3 DISCUSSION.

10.31 Anatomy.

The cornea in all the normal foals in this survey was clear, oval and broader nasally, and confirms the previous work of Latimer *et al* (1983) and Whitley (1990). The mild corneal oedema occasionally present in early neonatal life recorded by Whitley (1990) was not confirmed (figures 62 & 85). This may have been due to not examining enough foals close to birth.

The scleral shelf, or overhang, was recorded in 67% of foals, where a record was made. In all but 5 cases, it was present most prominently in the dorsal and ventral aspects of the eye (figures 55 & 87). The presence of the shelf in these areas diminished the view of the iridocorneal filtration angle and the pectinate ligaments. 62% of foals, where a record was made, had the presence of grey to blue-grey-white lines, which correspond to the insertions of the pectinate ligaments into the cornea at the termination of Descemet's membrane (figures 53, 58, 72 & 86). In all recorded cases these lines were evident on the temporal and nasal aspects of the eye, and in one case also dorsally (figure 63). This distribution of the grey lines appeared to be related to the incidence of scleral shelves dorsally and ventrally. The findings of this survey therefore confirm the work of Latimer *et al* (1983), Moore (1987) and Lavach (1990). Earlier authors, Huston *et al* (1977) and Gelatt (1982), suggested they might be abnormalities. The results of this survey would not confirm this. Even bearing in mind the high number of foals in which this finding was not recorded on the examination form, there was no relationship with any ocular abnormality. The high precentage of foals described with it, leads to the conclusion that it is a common normal finding in some foals and horses. The survey was unable to confirm the findings of Latimer *et al* (1983), that these lines can be apparent around the entire limbal circumference and that they are least obvious when conjunctival pigment is absent. In this survey, there was no relationship between foal coat colour, nictitans or conjunctival colouring, and pectinate lines, although there was a strong connection with iris colour and appearance. The lighter iris colours (see Chapter 12), grey-brown, grey and light brown were over represented. Iridescent iris appearance was also more common. Both iridescent and light iris colour are statistically related, and this may, therefore, affect their connection with other parameters. A possible explanation may be that the colour of the pectinate lines in the light coloured iris is often more blue-white facilitating observation.

The reason for the large number of foals with information not recorded on the scleral shelf/pectinate lines part of the examination form, is that this section was not introduced until approximately halfway through the survey, when interest in the subject was stimulated by a difference of professional opinion. The result and conclusions of this survey settle the dispute.

10.32 Congenital Abnormalities.

The low incidence (<0.5%) of corneal congenital abnormalities in the foal was confirmed by this survey (Gwin, 1983; Munroe and Barnett, 1984; Lavach, 1990).The one congenital abnormality in this survey did not conform with any of the well recognised types already discussed in this chapter. The congenital corneal vascularisation seen in foal 157 is very rare, and never seen by the author before (figures 63, 66, 73, 78, 88 & 89). A similar case is mentioned by Lavach (1990), quoting from Szutter (1961). He reports a temporary partial vascularisation and cloudiness of the cornea in foals, which cleared spontaneously within 2 weeks. Szutter (1961) suggested his cases were probably related to inflammation during foetal life and certainly the case in this survey would also lead this author to that conclusion. It was present early in the foal's life, at which time there was evidence of mild conjunctivitis possibly related to irritation. As time progressed, and presumeably as the inciting cause was removed, both the vascularisation and conjunctivitis resolved. There was no evidence of any other ocular or foal abnormality. Gelatt (1982) did record neovascularisation of the cornea in association with congenital corneal melanosis and thought the aetiology, again in these cases, was the result of intrauterine influences. If the irritation to the cornea/conjunctiva in this case did occur during intrauterine life, it appears that this did not affect the rest of the foal, or the gestational/parturition history.

10.33 Acquired Conditions.

2% of the foals in this survey had corneal conditions that were considered to be acquired. Latimer *et al* (1983) also found acquired corneal conditions to be the most common. They found 5 Thoroughbred foals on one stud with uni- and bilateral, superficial, irregular punctate corneal opacities which spontaneously resolved over the next 5 months. These were older foals and the possible aetiology of Equine Herpesvirus (EHV 1) was considered. Also recorded by Latimer *et al* (1983) were 3 foals with superficial corneal nebulae, and one foal with a healing corneal ulcer secondary to a previous entropion. Koch *et al* (1978) had 1 foal, in their survey, of an undisclosed age with a unilateral corneal opacity. They considered it to be a corneal scar or dystrophy.

In this survey, only one of the foals developed ulceration of the cornea, due to a foreign body (figure 91). This low incidence is most likely to be due to the early stage of their life at which they were examined. This decreased the likelihood of acquired corneal problems related to trauma, and the progression of others, such as ectopic cilia. Early examination of the foals with corneal problems in this survey allowed prompt evaluation and diagnosis, followed by effective treatment and a rapid response. Two foals in this group were good examples of this in that both had bilateral secondary entropion due to systemic illness, which was dealt with rapidly and effectively so preventing secondary corneal ulceration. As previously described in the literature (Whitley, 1990), the most common causes of acquired corneal disease in this survey were trauma, entropion, foreign body, and exposure keratitis in a comatose foal. Treatment in all cases consisted of removal of the initiating problem, antibiotic ophthalmic preparations to prevent secondary bacterial infection, and artificial tears to decrease ocular irritation and secondary desiccation.

The corneal foreign body found in this survey was unusual (figures 90, 91 & 92). Barnett and Bedford (1985), Whitley (1990), and Lavach (1990) state that plant material is the most common cause. The bilateral nature of this case and the offending material, hair, was most uncommon (figure 92). The problem appears to have arisen early in life and may be related to abnormal foal behaviour and the environment in which the foal was born. Considerable amounts of adult horse hair were present in the area, and it is possible that the foal trapped some into its conjunctival sacs while recumbent and attempting to stand. Once present in the sac, the movement of the globe and eyelids wound the hair into a tight ring, which came to lie in the central cornea. Without doubt early veterinary examination of the eyes helped prevent this hair causing major corneal damage. In one foal in the survey a corneal foreign body was noticed to have occurred between the examination and recording, and the photography. The material was flushed away with saline after photography. No corneal changes were apparent (figure 101).

The relationship of lack of vision and negative pupillary light responses, in the group of foals with corneal abnormalities, are more probably related to the effects of the primary systemic disease process than any obstruction to light by the corneal problem. The relationship shown in this survey between eyelid abnormalities and corneal problems is, however, well documented (Lavach, 1990).

CHAPTER 11.

THE SCLERA.

11.1 INTRODUCTION AND REVIEW OF LITERATURE.

11.11 Anatomy.

The sclera consists of three layers (Lavach, 1990). The episclera is superficial and contains the blood supply. The stroma is relatively acellular, poorly vascularised and the collagen bundles of which it is formed lack the regular arrangement of the cornea. Therefore, it scatters light and appears white. The lamina fusca joins the sclera to the suprachoroid and supraciliaris, and is heavily pigmented (figure 93).

The limbus is the transition zone between the cornea and sclera, where the corneal squamous cell epithelium changes to the bulbal conjunctival stratified columnar cells. It is often heavily pigmented (see Chapter 8) (figures 65 & 76). The overlapping scleral shelf (Peiffer, 1979) is uneven (see Chapter 10) (figure 87).

11.12 Congenital Scleral Abnormalities of the Foal.

There are no recorded congenital scleral abnormalities in the horse, other than scleral haemorrhages (figure 94). Scleral haemorrhages or splashing, and retinal haemorrhages, as well as apparent blindness and variable pupil size, were described in association with the clinical signs of convulsive foal or Neonatal Maladjustment Syndrome (NMS) (Mahaffey and Rossdale, 1957; Rossdale, 1969, 1972a & b; Barnett, 1975; Rossdale and Ricketts, 1980). These scleral haemorrhages are positioned over the sclera but are subconjunctival/conjunctival (bulbar) in position and thus, in recent veterinary and human literature, are called subconjunctival haemorrhages (Munroe and Barnett, 1984; Latimer and Wyman, 1985; Moore, 1987; Whitley, 1990; Lavach, 1990; Fukuyama, Hayasaka, Yamada and Setogawa, 1990; Katzman, 1992).

Subconjunctival haemorrhage is seen in newborn foals without NMS. It is thought to result from compressive trauma rupturing conjunctival and/or episcleral vessels during parturition (Latimer and Wyman, 1985; Latimer, 1987; Whitley, 1990; Lavach, 1990). The haemorrhage can be uni- or bilateral. A complete ophthalmic examination should be performed to reveal any other ocular abnormalities such as hyphaema, retinal haemorrhage and retinal detachment. The foal should be carefully examined to exclude the presence of other mucosal or cutaneous haemorrhage that might indicate a coagulopathy (Lavach, 1990). Other causes of conjunctival/subconjunctival haemorrhage in the adult horse that might occur in foals include vasculitis, anaemia, thrombocytopaenia, Disseminated Intravascular Coagulation (DIC), and the viral diseases: Equine Viral Arteritis (EVA) and Equine Infectious Anaemia (EIA) (Moore, 1987). Subconjunctival haemorrhages due to blunt trauma should resolve over 7-10 days without treatment (Latimer, 1987), although Lavach (1990), states that 3-4 weeks may be necessary. In severe cases, where a haematoma or chemosis is present, topical ophthalmic lubrication may be required (Whitley, 1990).

11.13 Acquired Scleral Abnormalities of the Foal.

The horse does not suffer from the specific inflammatory responses that affect the episclera and sclera in the dog (Whitley, 1990). It can, however, be traumatised and lacerated, often in association with the cornea, and this will lead to a poorer prognosis and increased likelihood of collapse of the globe (Lavach, 1990). Episcleral vascular injection has been recorded in severe, acute, anterior uveitis and glaucoma (Davidson, 1991).

11.2 RESULTS AND STATISTICS.

11.22 Scleral or Subconjunctival Haemorrhage.

Incidence.

A total of 14 foals (8.3%) had subconjunctival haemorrhages involving 20 eyes (5.9%). The left, right and bilateral distribution is shown in Table 11.1

L eye alone	R eye alone	Bilateral
5	3	6
(119,120,124,133,161)	(121,128,151)	(99,103,104,106,122,123)

Of these, 4 foals had subconjunctival and retinal haemorrhages combined (2.4% foals). All of these had bilateral subconjunctival haemorrhages (2.4% eyes). In this group, foals 103 and 104 had bilateral retinal haemorrhages, 99 right eye and 106 left eye only. Those with subconjunctival haemorrhages only included 10 foals (5.9%) and 12 eyes (3.5%).

Sex Distribution.

The distribution of subconjunctival haemorrhages in the two sexes is shown in Table 11.2

	No. of Foals	No. of Eyes	M	F
All Subconjunctival Haemorrhages	14	20	6	8
Subconjunctival Haemorrhages alone	10	12	5	5
Subconjunctival and Retinal Haemorrhages	4	8	1	3

Morphology.

The position, extent, colour and stage of resolution were recorded and are shown in Table 11.3

Foal	Retinal Haem.	Eye Distr.	Exam. Period (hrs.)	Position	Colour	Severity	Limbus	Remark
99	YR	B	<24	D	R	EXT	Y	F,S
103	YB	B	<24	D+V	R	EXT	Y	F
104	YB	B	<24	DT	R	Mo	Y	F
106	YL	B	<24	N	R	Mi	N	
119	N	L	<24	D+V	R	EXT	Y	F,S
120	N	L	24-48	D	R	Mo	Y	F
121	N	R	<24	D+N	R	Mi	Y	
122	N	B	<24	D+N	R	Mo	Y	
123	N	B	<24	D	R	EXT	Y	F
124	N	L	<24	D	R	Mo	Y	
128	N	R	72-96	N	P	Mi	Y	R
133	N	L	<24	N	R	Mi	N	R
151	N	R	<24	T	R	Mi	N	P,F
161	N	L	24-48	D (T>N)	R	Mi	N	P,F

Key.

Y = Yes D = Dorsal EXT = Extensive

N = No	V = Ventral	Mo = Moderate
R = Right	T = Temporal	Mi = Minimal
B = Bilateral	N = Nasal	S = Swollen
L = Left	D+V = Entire	F = Fresh
Colour	R = Red	P = Purple
	R = Resolving	P = Patchy

See Figure 8 for position of haemorrhages.

All the haemorrhages recorded were bright red in colour (figures 55 & 68), except foal 128 which showed resolving purple haemorrhages. This case was examined much later than the others, allowing time for resolution to start. A majority of the eyes with haemorrhages (13 of 18 eyes) showed extension up to the corneoscleral junction (limbus) along the entire length of the haemorrhage, especially where the degree of haemorrhage was described as moderate or extensive (figure 94). All 4 cases (5 eyes) not showing complete limbal extension (figure 55), were described as mild examples, 2 being patchy and uneven in appearance (figures 56 & 68).

The most common positions were dorsal (figure 68) and nasal (figures 55 & 56), with one case dorsotemporal (figure 94), one temporal and two entire (dorsal and ventral). The latter two entire cases were described as extensive in degree of severity. All the nasal positioned haemorrhages were described as mild (figure 56).

There was little significant difference in morphology between those foals with retinal and subconjunctival haemorrhages, and those with subconjunctival haemorrhages alone.

A wide ranging statistical analysis of the subconjunctival haemorrhage data, and possible associated parameters, was carried out. The small numbers involved may have had an adverse effect on the significance.

There was a very slight increase in incidence of haemorrhages in New Zealand bred foals. This could have been related to foal size (see Chapter 4), but direct analysis of the correlation between this parameter and the incidence of haemorrhage did not confirm this theory. A trend was, however, established in that only 2 foals with haemorrhages were less than 45 kgs. Foal sex, behaviour, colour and stand and suck time, were not related to the incidence of haemorrhages. Foaling difficulty or category did appear to affect the occurrence rate, with haemorrhages being the most common in Categories 3 and 4, and unusual in 1. Multiparous mares were overrepresented in the subconjunctival haemorrhage group. There was no relationship with gestational history, examination period, vision, menace and PLR reflexes, eyelid or nictitans problems, corneal abnormalities, or anisocoria. There may be a tenuous link between haemorrhage incidence and pupil size and optic disc colouration (increased numbers of red-pink and orange).

The relationship of subconjunctival (scleral) and retinal haemorrhages was examined in detail using a combination of the Chisquare Test of Independence and Fisher's Exact Test. Tests were carried out on subconjunctival versus retinal haemorrhages, bilateral subconjunctival versus bilateral retinal, left subconjunctival versus left retinal, and right subconjunctival versus right retinal. In all cases the low expected values in the Chisquare test invalidated the results. In none of the Fisher's Exact tests was there any evidence to support a relationship between subconjunctival and retinal haemorrhages.

11.23 Acquired Scleral Abnormalities.

3 foals were recorded with scleral abnormalities which were considered to have arisen since birth. The details of these scleral abnormalities are shown below.

63 Right eye. Episcleral injection of blood vessels. Related to direct ocular trauma (see Chapter 8). Left eye normal.

73 Right eye. Mild episcleral injection. Acute uveitis in foal with neonatal septicaemia. Bilateral secondary entropion (see Chapters 5, 7, 8, 10) (figure 34).

119 Bilateral with Left eye worse than Right. Episcleral blood vessel injection. Mild subconjunctival haemorrhage ventrally. Unattended foaling and NMS foal, with severe, self-inflicted, ocular trauma (see Chapters 5, 7, 8, 10) (figure 38).

All 3 foals had varying degrees of episcleral blood vessel injection, secondary to other ocular abnormalities.

11.3 DISCUSSION.

11.31 Subconjunctival Haemorrhages.

There has been no detailed survey of subconjunctival haemorrhages in the neonatal foal, although their presence is recorded in a number of major texts (Latimer and Wyman, 1985; Lavach, 1990; Whitley, 1990). The problem has been studied in the human neonate, with the first study by Baum and Bulpitt (1970) and, more recently, by Katzman (1992).

Incidence.

The incidence of subconjunctival haemorrhages in this survey was 8.3%. The incidence in the human baby varies from 2.9% (Fukuyama *et al*, 1990) to 29% (Katzman, 1992). The study from Japan, however, was not in neonates (Fukuyama *et al*, 1990). Baum and Bulpitt (1970) recorded an incidence, at 48 hours post-partum, of 7.2% and stated that this did not change significantly at different times from birth. This was, however, derived from a selected population, and an incidence of 31% was found in unselected infants. This survey confirmed that the equine neonatal incidence also did not change with examination period after birth. Originally it was suggested by Mahaffey and Rossdale (1957), Rossdale (1969, 1972a, 1972b), and Rossdale and Ricketts (1980), that scleral (subconjunctival) haemorrhage might be related to the Neonatal Maladjustment Syndrome and retinal haemorrhages. Later work has not confirmed this (Clement, 1987; Mayhew, 1988; Green and Mayhew, 1990; Brown, 1991). In this study 2.4% of the foals had both retinal and subconjunctival haemorrhages, but extensive statistical testing failed to detect any connection between the two entities. It is most likely that the combined percentage reflects the degree of overlap that might be expected, on a chance basis, considering the incidence of the two lesions. In this survey, foal behaviour, including time to stand and suck, was not related to the incidence of subconjunctival haemorrhage. It would appear unlikely, therefore, that subconjunctival haemorrhage is related to Neonatal Maladjustment Syndrome, or any other neonatal disease. In the human literature, the incidence of haemorrhages has not been linked to any neonatal condition or assessment, such as Apgar scoring (Yancey, Herpolsheimer, Jordan, Benson and Brady, 1991; Katzman, 1992).

There was no significant difference in eye distribution of subconjunctival haemorrhages in this survey, with the left, right, uni- and bilateral incidences being within statistical limits. This confirms previous statements made by Whitley (1990).

Sex Distribution.

8 female and 6 male foals had subconjunctival haemorrhages, and statistically there was no affect on the incidence by foal sex. Similarly, in the human, no direct connection to sex of the baby has ever been shown (Katzman, 1992). However, Baum and Bulpitt (1970) found a significant correlation of subconjunctival haemorrhage with birth weight and head circumference, both of which tend to be larger in male children. Earlier work in this survey established, however, that foal sex and birth weight were not related statistically, and it is therefore unlikely that foal sex could affect the incidence in this way.

Morphology.

The subconjunctival haemorrhages in this survey, with one exception, were bright red in colour (figures 55, 56, 68 & 94), suggesting fresh recent haemorrhage. The case which presented with purplish haemorrhage was considered to be resolving, and was examined much later (72-96 hrs.) than the others (majority <24 hrs.). The rate of resolution of subconjunctival haemorrhage in this survey was followed by regular return visits to affected foals. On average, resolution took 4-7 days after examination, depending on their initial severity and extent, although none were present at 10 days post-partum. Latimer (1987) and Whitley (1990) also suggested this timespan for resolution, although Lavach (1990) considered it may be 21-28 days. A foal at 24-48 hours post-partum is then more than likely still to have haemorrhages which appear fresh and red. Resolution in all of the cases in this survey was spontaneous, as it usually is in uncomplicated cases (Latimer, 1987). Subconjunctival haemorrhages in the newborn human are usually present soon after parturition, are slow to resolve, and often are present when the infant is discharged from hospital (Baum and Bulpitt, 1970).

The pattern of resolution in all the subconjunctival cases was similar, and consisted of the gradual shrinking of the size of the lesion, particularly on the non-limbal edges, accompanied by changes in colour (red -> purple -> brownish -> clear) and thickness (gradual thinning). There was no affect in the short or long term on vision, including menace or PLR reflexes, in any affected foals. Similar long term results are seen in human neonates (Yancey *et al*, 1991).

The majority of the foals in this survey with subconjunctival haemorrhage, showed extension up to the corneo-scleral junction or limbus (figures 55 & 94). This point is a transition zone of tissues and a relatively strong anchor point for the conjunctiva. The subconjunctival migration of the haemorrhage is prevented from expanding further into the cornea, and a dam-like effect ensues. Exactly the same appearance is seen in the human (Baum and Bulpitt, 1970). This will only happen when the haemorrhage is extensive enough and, when it is patchy or mild, it is less likely to show limbal extension (figures 56 & 68).

The degree of haemorrhage will reflect the amount of vascular damage (related to the cause), the extent to which it spreads before back pressure and clotting limit it, and also the amount of resolution. Extensive haemorrhages, in this survey, were associated with a more widespread position and some swelling of the conjunctiva. Their resolution rate was slightly slower than the mild examples, which were also more likely to be patchy and uneven.

The most common position for conjunctival haemorrhages to be found in this survey was dorsal or dorsonasal (10 of 14 foals) (figures 55, 56 & 68). Where the haemorrhage was extensive, the ventral quadrant was sometimes affected as well. The 3 nasal haemorrhages and 1 temporal haemorrhage were all mild (figure 56). The position of subconjunctival haemorrhages in the foal may reflect their aetiology, and does differ somewhat from that in the human where temporal and nasal are very much the most common sites. The author's opinion is that the dorsal scleral region is very much more exposed outside the bony orbit than other areas of the horse's eye. This is emphasised in the periparturiant foal, as it is delivered through the birth canal, by the common finding of the eye being turned downwards at this time.

Aetiology.

The aetiological factors involved in subconjunctival haemorrhages in the human neonate have been described by Baum and Bulpitt (1970). There was a significant positive correlation with high birth weight, large head circumference, gestational age, rapidity of second stage labour, Apgar score, and maternal parity. Children of Negro race were predisposed to the occurrence of haemorrhage. There was no association with neonate sex, mode of delivery, or the duration of first stage labour. More recently Katzman (1992) found no association between subconjunctival haemorrhages and perinatal factors such as: duration of membrane rupture, length of second stage labour, maternal weight and weight/length ratio, maternal injection of anti-inflammatory drugs, gravidity, birth weight, and Apgar score. There was a significant difference in incidence between vaginal delivered neonates as compared to those born by Caesarean section. Yancey *et al* (1991) found no difference in subconjunctival haemorrhage incidence between spontaneous vaginal and forceps assisted delivery, although Holden, Morsman, Davidek, O'Connor, Coles and Dawson (1992) disagreed with this.

In this survey, the incidence of subconjunctival haemorrhages was associated with foaling categories, especially 3 and 4, multiparity and, possibly, New Zealand bred foals. There was no association between foal sex or birth weight, behaviour, colour, gestational history, examination period, visual defects, eyelid abnormalities, corneal problems, anisocoria, and subconjunctival haemorrhages. A comparison of these findings with those of the human medicine workers reveals some consistencies, but overall the pattern is mixed. The possible affect of New Zealand breeding may, as has already been discussed, be due to increased birth weights in this group, although overall in this survey this parameter appears not to be a significant factor. Another possibility might include the higher incidence of category 3 and 4 foalings in New Zealand foals, which is, in this survey, related to an increased incidence of subconjunctival haemorrhages. Category 3 foalings (foetal oversize), and some types of problem in Category 4, are associated with increased compression on the foetal head and chest during delivery. Similar conditions to this are seen in traumatic facial cyanosis of the human baby, where tight pressure of the cervix around the foetal thorax leads to obstruction of venous drainage from the head and neck. This was associated with 100% incidence of subconjunctival haemorrhages in one survey (Baum and Bulpitt, 1970). The low incidence of haemorrhages in the human literature in newborns delivered by Caesarean section, as opposed to vaginal delivery, further points to this compressive theory.

Whether direct blunt optical trauma can cause subconjunctival haemorrhages is difficult to determine. In the human literature there is some dispute as to the affect of forceps delivery on haemorrhage incidence although, in one survey (Holden *et al*,1992), there was a doubling after forceps use. Lavach (1990) and Latimer and Wyman (1985) suggest that blunt trauma is a cause. The results of this survey support this view in that, in Category 3 and 4 foalings, the increased pressure on the foetal head could have lead to blunt trauma. Interestingly Category 5 foalings did not have a higher incidence, but the small numbers involved make interpretation of this fact difficult.

There was a significant correlation of multiparity and the incidence of haemorrhages in this survey, which agrees with the human survey results of Baum and Bulpitt (1970), but not Katzman (1992). Although multiparity is associated with increased birth weights in this survey, it has already been suggested that this does not directly affect the incidence of haemorrhage. Indirectly, it might increase the chance of foetal oversize (Category 3) foalings, but in this survey foetal oversize was more common in the uniparous mare. It is possible that the effect of multiparity is a combination of birth weight, foetal oversize (possibly increased head and thorax size but not overall weight), and the speed and magnitude of delivery forces in the older mare. In the human, multiparity is associated with a more rapid second stage of labour and certainly, in the author's opinion this is also true in the horse.

In all the human literature, and in this survey, there is no correlation between subconjunctival haemorrhages and abnormal neonates. The affect of the race (Negro) on the incidence of haemorrhages in the human was noted (Baum and Bulpitt, 1970), and thought to be partially due to the higher incidence of haemorrhagic disease of the newborn in this group. Causes of subconjunctival haemorrhage in the adult horse include coagulopathies, immune mediated diseases, and certain viral infections (Latimer, 1987). Immunological deficiencies have also been cited as a cause in the foal (Lavach, 1990). None of these conditions were seen in the foals in this survey on clinical or blood examination. The long term effects of this condition in general, and in ocular terms, in the foals in this survey was insignificant. As already discussed in previous chapters, the clinical history of the neonate is related to gestational and parturition events and, in this survey and the human ones, no correlation between gestational abnormality and subconjunctival haemorrhages was found. There was, however, a slight trend towards full term or slightly overdue gestational length. These facts, alongside the important factor of foetal oversize in this survey, tend to suggest that the aetiology of subconjunctival haemorrhages is probably an exaggerated manifestation of normal changes seen in the periparturient neonate.

Fukuyama *et al* (1990) and Pitts, Jardine, Murray and Barker (1992) have described the major causes of subconjunctival haemorrhage in the human to be local blunt trauma and systemic hypertension. Baum and Bulpitt (1970) and Katzman (1992) proposed that the majority of the subconjunctival haemorrhages in the human neonate were a consequence of elevated venous pressure in the head and neck, due to obstruction of the veins. This was produced by compression of the foetal thorax and/or abdomen by uterine contractions. Rossdale, Jeffcott and Palmer (1976) measured jugular venous pressure in the foal during normal delivery, and found peak pressures of 60-200 mmHg, and also carotid arterial pressures of 175/100 mmHg. These are hypertensive and were thought to be due, as in the human, to thoracic compression. Other authors have proposed compressive or blunt direct ocular trauma during the birth processes in the foal (Latimer and Wyman, 1985). It seems possible from the results in this survey, therefore, that increased peripheral venous pressure and, in addition, direct compressive blunt trauma to the orbit during passage through the birth canal, are the main factors involved in the pathogenesis of subconjunctival haemorrhage in the foal.

11.33 Acquired Scleral Abnormalities.

All the 3 foals with acquired abnormalities had injection of the episcleral blood vessels. These vessels must be differentiated from those of the overlying conjunctivae by assessing their position and nature, whilst carefully examining the conjunctiva for evidence of inflammation. All 3 foals had episcleral vessel injection secondary to other ocular abnormalities. 2 were due to blunt ocular trauma of self-inflicted aetiology, 1 of which had severe conjunctivitis and chemosis; the other a severe acute anterior uveitis. In all, 2 of the foals had episcleral blood vessel injection due to uveitis and were blind in this eye. This is in agreement with Davidson (1991) and suggests, therefore, that any foal with episcleral blood vessel injection should receive a thorough ocular examination to detect other major ocular problems.

CHAPTER 12.

IRIS, PUPIL AND CILIARY BODY.

12.1 INTRODUCTION AND REVIEW OF LITERATURE.

12.11 Anatomy and Normal Appearance.

Iris and Ciliary Body.

The iris, the ciliary body and the choroid are collectively referred to as the uvea or uveal tract (Barnett and Bedford, 1985). The iris and ciliary body constitute the anterior uvea. Embryologically they are derived from primitive mesoderm and neuroectoderm (Matthews and Crisipin, 1987a). The iris arises from the anterior part of the ciliary body and presents as a disc of tissue composed primarily of stromal elements and muscle fibres. It divides the eye into anterior and posterior segments and, by the sphincter activity of the centrally positioned pupil, it controls the amount of light entering the posterior segment (Barnett and Bedford, 1985). Iridal activity, miosis, helps sharpen the visual image and increase depth of focus. The posterior surface of the iris is in contact with the anterior lens capsule, and thus bows forward slightly (Appendix 2). The iris surface is not smooth but consists of small furrows and folds. Thread-like filaments extending from the collarette region may represent pupillary membrane remnants (see later sections).

The microscopic anatomy of the iris (figures 81 & 95) consists of an anterior border endothelial layer; the stroma, comprising the bulk of the iris; the iris musculature; and a double epithelial layer covering the innermost portion of the iris (Lavach, 1990). The stroma is usually heavily pigmented with melanin and contains melanophores, connective tissue, vessels and nerves. The vasculature of the iris consists of a major peripheral arcade and radial arteries (figure 96) continuing towards the pupil to form an incomplete circle (Anderson and Anderson, 1977). The iris musculature (figure 81) is unique since it is derived from neuroectoderm. The sphincter muscle, occupying the major portion of the central stroma near the pupil, is under parasympathetic control, and is responsible for pupillary constriction (Martin and Anderson, 1981). The dilator muscle receives a sympathetic innervation, and is more prominent in the dorsal and ventral quadrants (Prince *et al*, 1960, quoted in Lavach, 1990). Contraction leads to mydriasis. The double epithelial layer is a continuation of the ciliary body epithelium and the cells are heavily pigmented, even in lightly coloured irides (figures 95 & 201).

The ciliary body (figure 81) is primarily involved in the production and drainage of the aqueous, and thus the balance of intraocular pressure. It also helps to maintain the position of the lens by providing anchorage for the suspensory zonule (Barnett and Bedford, 1985). The pars plicata bears the ciliary processes, and it is these structures that are responsible for aqueous production. The bulk of the drainage of the aqueous from the anterior chamber of the eye is via the ciliary cleft, a recess in the lower part of the anterior face of the ciliary body. This contains the trabecula meshwork, and communicates with the intrascleral venous plexus (Samuelson, Smith and Brooks, 1989; De Geest, Lauwers, Simoens and Schaepdrijer, 1990). Patency of the cleft is vital, with any denial of drainage causing glaucoma, usually secondary to uveitis in the horse. The bulk of the ciliary body consists of smooth muscle fibres, and spasm of these in anterior uveitis is painful. The muscle has a parasympathetic innervation. The ability of the ciliary muscles to assist in equine eye accommodation is limited (see Chapter 5).

Colour and Appearance.

The colour of the iris is dictated by the amount of melanin present in the stroma and epithelium (Barnett and Bedford, 1985). In foals and adults, (figures 59 & 108) the most common colour, regardless of coat colour, is a dark brown, which may be homogenous or mottled with tan or grey towards the periphery (Latimer *et al*, 1983; Munroe and Barnett, 1984). Lavach (1990) stated that three subtle colour zones can be recognised in many neonatal foals: the pupillary zone, reddish to dark brown; the collarette region, bluish grey; and the peripheral zone, dark brown. Changes in these zones may occur as the horse ages (Tuchlinski, 1935, quoted by Lavach, 1990). Other iridal colours include lighter shades of brown, gold, blue and white (figure 201). Colour dilute irides are seen in Appaloosas, Pintos and some ponies, but are rare in Thoroughbreds. Sectorial variation (figure 109) can also occur and the irides are not always symmetrically coloured. Heterochromia iridis is a term used to describe a colour variation between the two irides, or two or more colours in one iris (figure 97).

Intraocular inflammation, trauma or haemorrhage can affect the iridal colour and appearance, either temporarily or permanently (figure 39).

Pupil.

The adult equine pupil is horizontally ellipsoidal (figures 108 & 201) (Gelatt, 1982; Barnett and Bedford, 1985; Lavach, 1990), and the upper margin is characterised by the presence of 3 or 4 granula iridis (corpora nigra) (see next section). The horizontal shape is due to the presence of dilator fibres in the upper and lower quadrants (Prince *et al*, 1960, quoted by Lavach, 1990). The equine pupil is more tonic and seems in a semiconstricted state when compared to other domestic animals. The shape of the pupil is affected by the level of ambient light, and ocular/neurological pathology. The neonatal pupil (less than 24 hours old) is bilaterally symmetrical, large and circular (in a position near maximal dilation) (figure 98) (Barnett, 1975; Gelatt, 1982; Frauenfelder, 1983; Munroe and Barnett, 1984). A roughly oval shape with a closer-to-adult resting position is generally present in older foals (5 days onwards), with the adult appearance present within 7-14 days (Latimer *et al*, 1983). The nasal portion is slightly wider than the temporal (foal 0.3-1mm. wider) (Latimer *et al*, 1983) and also slightly deviated below the horizontal plane (Adams and Mayhew, 1985) (figure 85) .

The pupillary light reflex has been discussed in detail in Chapter 5. The size and shape of the pupil after stimulation with a bright focal light source, and following mydriasis (tropicamide), has been documented in the older foal (over 5 days) (Latimer *et al*, 1983). This involved an accurate measurement, in millimetres, of the temporal and nasal widths.

Corpora Nigra (Granula Iridica).

The pupillary margin of the iris is lined by a pigmented ruff which is an extension of the posterior segment epithelium. The central upper and lower margins have exaggerated prominences which are given various names, including the two above (Laszlo, 1936; Martin and Anderson, 1981; Barnett and Bedford, 1985). The corpora nigra are present in all foals dorsally, but their occurrence ventrally is more sporadic and less striking (figure 57) (Koch *et al*, 1978; Latimer *et al*, 1983; Munroe and Barnett, 1984). Only approximate bilateral symmetry exists. Lavach (1990) quoting Wajgiel (1935) states that 6% of adults lack corpora nigra entirely and 2% had unilateral corpora. The corpora nigra usually consist of 3 or 4 large and pigmented, solid, black, irregular or sometimes spikey, bodies (figure 81). Each one represents a cystic prominence of the posterior pigment epithelial layer of the iris. Anderson and Anderson (1977) showed that the corpora were smaller in a 1 week old foal, but had reached approximately adult size by 1 month old. The function of the corpora nigra remains unclear, but Prince *et al* (1960) and Gelatt (1982) propose that they facilitate pupillary function and increase the effectiveness of the pupil, by restricting passage of light.

12.12 Congenital Abnormalities of the Foal's Eye.

In contrast to acquired diseases of the uvea, especially inflammation, congenital abnormalities are rare (Riis, 1981).

Anomalies of Pigmentation.

These anomalies are observed most frequently in lighter coloured horses, especially white, cream, spotted, chestnut, or palomino types. There is evidence that pigmentation variations may be inherited in the white horse (Munroe and Barnett, 1984). Heterochromia iridis (figures 64, 97, 109 & 201) occurs occasionally and may affect portions of one iris, portions of both irides, one entire iris, or both irides. Those animals with Welsh pony in their ancestry are relatively commonly affected. Colours in heterochromia are usually combinations of brown, white and blue (Gelatt, 1982). A mixed blue and white iris is called a "wall eye" (figure 201) (Lavach, 1990), and an evenly blue or white pigmentation, a "china eye" (Gelatt, 1982; Munroe and Barnett, 1984; Lavach, 1990). A "glass eye" refers to the condition in which the iris has no pigment and appears pink (albinism) (Munroe and Barnett, 1984). Particular ophthalmic conditions associated with anomalies of iridal pigmentation, except for iris cysts (figure 110), have not been reported (Munroe and Barnett, 1984). They frequently occur in combination with retinal and choroidal pigment anomalies, and should be considered normal variants rather than abnormalities (figure 99). They may be related to coat colour variation and carriage of colour-dilute genes (Rebhun, 1991). Discrete foci of dense pigmentation are occasionally observed on the anterior iris of grey horses. Their significance is unknown but they may represent benign melanophore concentrations (Matthews and Crispin, 1987a).

Aniridia.

Aniridia is the complete absence of the iris, and is rare both histologically and gonioscopically (Latimer and Wyman, 1985). The term is used clinically, however, when an apparent absence of iris tissue allows visualisation of the lens equator and ciliary processes (Eriksson, 1955; Joyce, 1983; Irby and Aguirre, 1985; Ueda, 1990). The new term, iridal hypoplasia, has been proposed as a more appropriate designation for these cases (Yanoff and Fine, 1989; Joyce, Martin, Storts and Skow, 1990). Aniridia has been seen in combination with other ocular defects (Joyce, 1983). Bilateral aniridia, with associated secondary cataracts and dermoids, and inherited as an autosomal dominant trait, has been reported in Belgian draft horses (Eriksson, 1955). Joyce (1983) and Joyce *et al* (1990) reported the condition in association with limbic dermoids and cataracts in the Quarterhorse, Irby and Aguirre (1985) in a Welsh cross thoroughbred pony, again along with cataracts, and Ueda (1990) in a Thoroughbred. The condition was inherited in the Quarterhorses.

Clinical examination reveals an abnormally large, unresponsive, round pupil bilaterally, with the equator of the lens and ciliary processes visible. There may be photophobia, blepharospasm, and lacrimation. Other abnormalities of the cornea and lens may be present. Vision may or may not be affected (Gelatt, 1982; Joyce, 1983; Joyce *et al*, 1990). Several theories on the aberrant development have been proposed to explain aniridia, but failure of sufficient mesodermal ingrowth is the most widely accepted (Wilcock, 1983).

Coloboma.

Segmental partial or complete absence of iris tissue may occur as the sole defect, or in association with ciliary body, choroidal or lens colobomata (Wilcock, 1983). They may affect the pupillary margin, or appear as holes within the iris substance. The condition may be hereditary in some species, can be uni- or bilateral, and causes variations in pupil size and shape (Munroe and Barnett, 1984). A failure of closure af the embryonic fissure accounts for iris colobomas associated with fundic and optic nerve colobomas in the inferionasal quadrant (typical coloboma) (Wilcock, 1983). All other segmental defects are atypical and of unknown pathogenesis (Latimer and Wyman, 1985). They produce clinically insignificant lesions that do not impair vision.

Anterior Uveal Cysts.

Three types of cyst arise from the equine iris (figure 100) (Matthews and Crispin, 1987a; Lavach, 1990) but none have been reported in foals (Latimer and Wyman, 1985). They occur in approximately 4% of horses (Szutter, 1936). Their exact aetiology is unknown but some are probably congenital.

Stromal cysts (figure 110) (Matthews and Crispin, 1987a) develop in the posterior iris, possibly in association with thin irides, as a result of stromal iris atrophy. These often bulge into the anterior chamber and have been observed in association with heterochromia iridis, particularly in older ponies, in the superior basal iris (Rubin, 1966; Lavach, 1990). They can become quite large, but seldom involve the pupillary margin, and do not usually interfere with vision. Some may be translucent (Roberts, 1992b). These cysts may represent a developmental abnormality (Riis, 1981, Wilcock, 1983) or an ageing change (Gelatt, 1982).

Cysts of the posterior pigment epithelium can arise and extend over the pupillary margin, occasionally distorting the pupil, or break off and float into the anterior chamber (Szutter, 1936; Matthews and Crispin, 1987a). They may eventually adhere to other structures. They can be uni- or bilateral, and are often thin-walled and transilluminate. They seldom interfere with vision, although occasionally they may enlarge to such an extent that they obstruct the pupil and impinge upon the corneal endothelium. Surgical rupturing or excision may then be necessary. Spontaneous rupture may also occur.

Cystic enlargement of the granulae iridica are occasionally observed and are very similar to the posterior pigment epithelium type. Lavach (1990) reported a Thoroughbred foal in which, typically, the cyst grew rapidly from birth such that at 6 months old it occupied two thirds of the anterior chamber. Treatment with needle aspiration or laser is possible (Davidson, 1991). Cystic enlargements require differentiation from hypertrophic corpora nigra which do not transilluminate and usually affect the upper pupillary margin only.

Persistent Pupillary Membrane (PPM).

These remnants of iris embryogenesis are commonly observed in young foals (figure 82) (Latimer *et al*, 1983; Munroe and Barnett, 1984). The membrane is derived from the iris mesenchyme, constituting the anterior vascular sheath (anterior tunica vasculosa lentis) for the lens, and forming a delicate membrane stretching across the pupil (Munroe and Barnett, 1984). The membrane normally atrophies in early life but, where this is incomplete or delayed, remnants persist as strands attached to the lesser circle or collarette of the iris (Lavach, 1990). The pigmented strands arise from the iris stroma about midway between the pupillary margin and the iris base. When they protrude from the iris surface, or traverse the iris face and insert elsewhere on the iris, PPM's cause few problems (Latimer and Wyman, 1985) (figure 62). Strands that traverse the anterior chamber to fuse with the cornea are associated with non-progressive deep corneal opacities at their site of attachment, whilst those that attach to the lens capsule are often associated with anterior capsular or cortical cataracts, which may be progressive

(Wilcock, 1983; Munroe and Barnett, 1984). Remnants can also be associated with other abnormalities such as microcornea, cataract and iris coloboma (Riis, 1981). An hereditary pattern has not been identified and treatment is not recommended (Lavach, 1990).

Glaucoma.

Glaucoma is a condition in which the intraocular pressure is sufficiently elevated to cause damage to the intraocular structures. Congential glaucoma is very rare in the horse, and especially so in foals. It often occurs with buphthalmos (Gelatt, 1982) because the young eye is more easily stretched. It may be hyper-, hypo-, or normo-tensive (Lavach, 1990). It has been discussed previously in Chapter 6.

Pupillary Shape.

Congenital malformation of the pupillary shape is rare in the foal. Some of the conditions already described in this chapter alter the shape of the pupil. In fact this is often the first abnormality that owners or veterinary surgeons notice. Foals with multiple ocular abnormalities, including microphthalmos, may have unusual pupillary shapes (figure 96).

12.13 Acquired Diseases of the Anterior Uvea in Neonatal Foals.

Acquired diseases of the anterior uvea are one of the most common intraocular problems to be dealt with in the adult equine eye. They do occur in the foal, including the neonate, though perhaps not as frequently.

Anterior Uveitis.

This term encompasses both iritis and the commonly concurrent cyclitis and anterior choroiditis, under one heading (Crispin and Matthews, 1987b). In neonatal foals anterior uveitis is usually associated with systemic bacterial or viral infection (figure 35). Possible causes in the neonate include E. coli, Salmonella spp., Actinobacillus equuli, and occasionally other bacteria involved in the neonatal septicaemias/bacteraemias (Whitley, 1990). Infections are derived from in utero sources such as placentitis, during parturition, or in early neonatal life from the immediate environment, particularly where the foal is colostrum deprived or premature/dysmature. Localisation of the bacteraemia can lead to multiple system/organ dysfunction with subsequent infection in the eye or, more commonly, inflammation rather than infection. This inflammation is immune mediated through previously sensitised lymphocytes in the uvea, circulating bacterial toxins, vasoactive mediators, and immune complexes (Slatter, 1981).

In slightly older foals (1 month or older), Corynebacterium (Rhodococcus) equi may cause hypopyon and anterior uveitis, along with signs of systemic disease (Blogg *et al*, 1983). In the still older foal, Streptococcus equi and the viral diseases, Equine Viral Arteritis (EVA) and adenovirus infection, have all caused anterior uveitis, hypopyon, blepharospasm and photophobia (Latimer and Wyman, 1985).

Clinical signs of anterior uveitis in foals include hypopyon, hypotomy, corneal oedema, corneal vascularisation, miosis, aqueous flare, loss of iris detail and change in iris colour. The hypopyon reflects a marked alteration in vascular permeability and is usually sterile.

Treatment of the eye in these cases requires appropriate systemic therapy and supportive care, plus topical antibiotic/corticosteroid and cycloplegic ophthalmic ointments, and a systemic prostaglandin inhibitor to help reduce inflammation. The goal of treatment is to minimise structural alterations, such as synechiae and cataracts, so that subsequent function is satisfactory.

Other causes of iridocyclitis in the neonatal foal include blunt trauma, either through the eyelids or directly against the cornea (figure 39). Shock waves are transmitted through the eye damaging a variety of structures including the lens, iris and ciliary body, and triggering an immune mediated uveitis via uveal mast cells (Crispin and Matthews, 1987b). The degree of response and subsequent clinical signs vary with the severity of the injury, however, treatment is very much as described for anterior uveitis due to infection.

Severe episodes of anterior uveitis can severely, and permanently, damage the affected eye leading to chronic changes. These include anterior/posterior synechiae, ruptured granula iridica, pupillary seclusion and occlusion, iris colour changes, iris atrophy, cataract formation, vitreous changes, and non-specific fundic lesions such as peripapillary chorioretinitis. Phthisis bulbi, rather than glaucoma with hydrophthalmos, is the most severe sequel (Crispin and Matthews, 1987b).

12.2 RESULTS AND STATISTICS.

12.21 Anatomy and Normal Appearance.

Iris Colour.

The colour of the iris was recorded and the results are shown in Table 12.1

(DB) Dark.Brown	93	55%
(GB) Grey Brown	65	38.5%
(G) Grey	10	5.9%
(LB) Light Brown	1	<1%

No other colours were recorded (figures 61, 62, 75, 76, 98, 102 & 103).

Appearance.

The results of the appearance of the iris are recorded in Table 12.2.

Mottled	Iridescent	Homogenous	Other
74 DB	1 DB	18 DB	2
51 GB	21 GB	3 GB	
7 G	7 G	1 G	
0 LB	0 LB	1 LB	
132 (78%)	29 (17%)	23 (14%)	

(Figures 53, 61, 62, 73, 85, 86 & 104)

10 foals had both mottled and iridescent appearance in the grey-brown colour group and 5 foals in the grey iris colour. The 2 foals with the other category of iris appearance are discussed in the acquired iris abnormality section.

There was, overall, a weak statistical relationship between iris colour and foal coat colour. Dark brown iris colour was overrepresented in the bay coat colour and, to a lesser extent, brown and black; grey-brown, grey, and light brown iris colour were more common in the chestnut and grey coat colours.

The appearance of the iris is related significantly to the iris colour, but only in the iridescent and homogenous groups. The presence of mottling is not related to iris colour. The incidence of iridescence is strongly associated with grey-brown and grey iris colour, whereas homogeneity is much more common in dark brown iris colour. Overall, the appearance of the iris is not statistically related to foal coat colour but certain trends do exist. Mottled appearance is slightly more common in the bay coat colour, whereas iridescence is much more common in the chestnut and grey foals.

Nictitans colour or pigmentation has already been shown to often relate to coat colour and, therefore, not surprisingly, it also has a significant correlation with iris colour and appearance. Dark brown iris colour, and/or mottling, is often seen with pink, black edge nictitans and whole pink with grey-brown, grey, light brown, and/or iridescent iris.

The correlation of iris colour and appearance with the presence of scleral shelf/pectinate ligaments has already been described in Chapter 10. The presence of a ventral corpora nigra was also positively related to iris colour, but not to iris appearance. The relationship of the iris colour and appearance with fundic appearance was examined. The iris appearance has no correlation with any of the fundic parameters examined, but the iris colour has quite strong statistical relationships with optic disc colour, tapetal/non-tapetal border appearance, and non-tapetal fundus colour. Pink optic disc colour appears more common in the dark brown iris, and pale pink in the grey-brown and grey categories. The presence of red choroid vessels in the fundus is not significantly related. The ragged border category is overrepresented in the dark brown iris group, whereas the grey-brown iris is related to the extension of the border towards the disc. In the non-tapetal area of the fundus, dark brown colouration, and possibly the presence of atypical colobomas, is more common in the dark brown iris; whereas light grey-brown non-tapetal colour and dorsal-to-disc depigmentation is overrepresented in the grey-brown iris.

The tapetal fundus colouration does not appear, superficially, to be related to iris colour, but if the affect of small numbers of certain, rather unusual, foals is removed from the Chisquare equation, there does emerge a pattern. Dark brown iris colour is most commonly seen in association with yellow-green or yellow/green border tapetal colour. Grey-brown and grey iris colour is often related to a green-yellow tapetum.

Pupil.

The resting pupil size and shape, and its change after PLR stimulation is shown in Tables 12.3, 12.4, and 12.5.

The figures relate to a percentage system of classifying the pupil constriction/dilation. A figure of 100% is maximal dilation acheivable by mydriasis in the foal and 0% is complete miosis. A figure of 50% would correlate with the normal resting pupil size of the equine eye (adult) in the ambient light of the average stable in which the foals were examined. Therefore, a pupil halfway between the resting level and maximal dilation would be 75%.

KEY

C = Circular

O = Oval

E = Elliptical

? = Unrecorded after PLR or Insignificant change

50/60 etc. = Between these two limits

Table 12.3

80 > 70 C > O 31	75 > 70 O > O 17	80 > ? C > C 17 (1xd0)	70 > 50 O > O 11 (1xd5)
80 > 70 O > O 11	70 > ? E > E 11	80 > 50/60 C > O 10	70 > 60 O > O 9
85 > 70 C > C 6	70 > 65 O > O 5	80 > 65 O > O 4	70 > ? O > O 5
75 > ? O > O 4	80 > 75/70 C > E 4	60 > ? E > E 3	75 > 60 E > O 3
75 > 60 O > O 3	80 > 75 O > O 2	60 > 50 O > O 2	75 > 70 C > O 1
50 > ? O > O 1	80 > 75 E > E 1	85 > 75 C > O 1	75 > 70 E > E 1
50 > ? E > E 1	Unrecorded 2	Anisocoria 4	

Table 12.4

Resting Pupil Size %		Stimulated Pupil Size %	
90	1	90	0
85	6	85	0
80	80	80	23
75	29	75	12
70	40	70	77
65	0	65	9
60	5	60	18
55	0	55	0
50	2	50	24
TOTAL	163		163

Table 12.5

Resting Pupil Shape		Stimulated Pupil Shape		
C	70	**C**	6	
O	73	**O**	109	
E	20	**E**	4	
				17 **C**
		No change	44	10 **O**
				17 **E**
TOTAL	163		163	

Over 50% of the resting pupils were 80% or greater in degree of dilation (figures 74 & 98) and 95% were >70% dilated (figures 49, 54 & 104). After PLR stimulation the degree of dilation spreads out such that 14% were 80% or > and 69% were >70% dilated. The mean resting pupil size is 75% and the mean stimulated pupil size is 67.5% .

43% of pupils are circular at rest (figures 74, 98 & 104), with a further 45% being a broadened oval shape (figures 47, 105 & 106). Only 12% have the adult elliptical shape at rest (figures 57 & 107). After stimulation only 14% are circular, 73% have now become oval, and 13% elliptical. 27% of foals did not change shape after stimulation.

The most common combinations to describe the neonatal pupil at rest, and after stimulation, are shown in Table 12.6

At Rest			**After Stimulation**		
%Shape			**%Shape**		
80-85 C	69	(42%)	80 C	23	(14%)
80-85 O	17	(10%)	75 O	7	
70-75 C	1		75 E	5	
70-75 O	53	(33%)	75 C	0	
70-75 E	15	(9%)	70 O	65	(40%)
< 70	8	(5%)	70 E	12	(7%)
			65 O	9	
			60 O	15	(9%)
			60 E	3	
			50 E	1	
			50 O	23	(14%)
TOTAL	163			163	

At rest 42% of foals had pupils which are circular and greater than 80% dilated. 43% had oval pupils of between 70-80% dilation. Only 9% of foals had the adult shape, but a slightly greater degree of dilation.

After stimulation only 14% of foals had circular, 80% dilated pupils, but 40% had oval pupils with 70% dilation. Almost 25% of foals had less than 70% dilation, with mainly oval shape. There is a noticeable widening of the spread of dilation percentage and shape.

Pupil size, in general, was found not to have any significant association with foal size or sex, foaling category, or blink reflex. There is a relationship with foal behaviour and vision, menace and PLR reflexes including rapidity, and examination period. Pupil shapes in general, seem to have no relationship with any parameter, except pupil size, and a marginally significant association with examination period.

Anisocoria.

Only 4 foals with anisocoria were recorded. These were not included in the analysis of pupil size. The details of the 4 cases are given below.

62 Normal foal in all categories. Normal pregnancy/foaling.
Examined at 12 hours old.
Left eye 85% circular > 80% oval. Menace -ve. PLR +/-
(i.e. PLR abn. +).
Right eye 75-80% oval > 70% oval. Menace -ve. PLR +/-.
No ophthalmic abnormality.
Re-examined at 36 hours. No abnormality detected.

73 Septicaemic foal (see Chapter 4)
Left eye secondary entropion. Pupil 70% oval > 60% oval.
Menace -ve. PLR +/-.
Right eye acute uveitis d4 onwards. Blind.
Complete miosis before treatment. PLR -ve. Photophobic.

111 NMS foal (see Chapter 4). Examined at 15 hours after birth
(13 hours after convulsions) whilst heavily sedated.
Left eye complete miosis. PLR -ve. Blind.
Right eye 60% circular. PLR -ve. Papilloedema.
Retinal haemorrhages.

20 hours after birth:

Pupillary shape as before but Left eye miosis decreased.

Still blind.

38 hours after birth:

Clinical improvement throughout day.

Standing.

Pupils Left and Right same size at 60% oval. PLR +/-.

Menace -ve. Decreased Papilloedema. Visual.

60 hours after birth:

Pupils Left and Right same size. 60% oval. PLR +/-.

Papilloedema negative. Menace +/-. Visual.

119 ? NMS foal with self-inflicted trauma (see Chapter 4).
Examined within approximately 12 hours (unattended birth).
Left eye photophobic. PLR and Menace -ve.
Oval 70% with distorted pupillary margin and possible synechiae.
Right eye no response to light. PLR and Menace -ve.
Complete miosis. Died within 24 hours.

Three of the anisocoria foals were systemically severely ill (1 Group I, 2 Group II), with two having acute uveitis unilaterally (see Chapter 12.23). The foal with NMS showed a return to complete normality of behaviour, the progress of which very closely paralleled the disappearance of the anisocoria. Statistical analysis on the small numbers involved, as previously noted, is open to misinterpretation. Anisocoria does appear, however,to be strongly connected with abnormal foal behaviour, including stand/suck times and visual and PLR deficits. It is not related to foaling category, examination period, scleral or retinal haemorrhages, optic disc colour or character.

Corpora Nigra.

The incidence and size of corpora nigra are shown in Table. 12.7. All were bilaterally similar, except in foal 73.

Incidence

Dorsal	169
Ventral	125

Size

Dorsal:	Large	Normal	Small	Abnormal
	5	161	1	2
Ventral:	V. Small	Small	Large	Absent
	3	117	4	44
	Abnormal			
	1			

All 169 foals had dorsal corpora nigra present of which 161 (95%) were considered of normal size for a foal (figures 54, 57, 58 & 61). 1 was smaller than normal (figure 103), 5 larger (figures 59 & 71) and 2 were abnormal (both with uveitis).

125 foals (74%) had ventral corpora nigra as well, and 117 of these (94%) were considered small (figures 54 & 57), especially in comparison with the dorsal corpora nigra. In 4 foals they were larger than normal, 3 very much smaller (figure 106) and 1 was abnormal (uveitis).

The presence or absence of the ventral corpora nigra is not associated with foal sex, examination period, PLR, iris appearance, PPM, border appearance, or tapetal/non-tapetal fundus colour. The presence of ventral corpora is slightly higher in bay and bay-brown foals and slightly less in chestnut, although this is not statistically significant. Although not significant, there is a trend for a higher and lower incidence in nictitans colour categories 2 and 1, respectively. The relationship to iris colour is significant and is the opposite to that expected based on coat colour affects i.e. higher incidence in grey-brown and lower in dark brown iris colour. Ease of detecting the small ventral corpora nigra in the lighter iris may have affected the results.

12.22 Congenital Abnormalities.

The only congenital abnormality of the iris, pupil or ciliary body that was detected in this survey was persistent pupillary membrane.

Persistent Pupillary Membrane.

14 foals were found to have remnants of the anterior pupillary membrane. The details of these foals are shown in Table 12.8

Foal	Bilateral	Collarette	Other Types	Other Related Ophthalmic Changes
16	*	small		
26	*	v. small		Bil. hyaloid
61	*	v. small		R. hyaloid
90	*	pupillary edge		Bil.hyaloid. Post. PM.
110	*	v. small dorsal and ventral		
123	*	v. small		Bil. hyaloid
125	*	short intermittent		
128	*	short intermittent		
135	*	short		Bil. hyaloid
148	*	short		Bil.hyaloid. sl. Post PM.
150	*	short		
153	*	short		Bil. hyaloid
154	*	short		Bil. hyaloid. ext. Post PM.
155	*	small		Bil. hyaloid. ext.Post PM.

The only foals examined for the presence of very small tags etc. were those from 1986 onwards i.e. 18 NZ + 44 UK = 62 in total. No foals had any long tags or adhesions to the lens or cornea. 14 foals (22.5%) had some remnant of the pupillary membrane. 8 foals had a complete collarette, albeit small (figure 59). The longest tags off the collarette extended to the pupillary margin. 6 foals had incomplete collarettes and very small tags (figures 62, 86 & 102).

The presence of any persistent pupillary membrane (PPM) was not associated with foal sex, colour or behaviour, examination period, PLR, or iris appearance. It did seem to be significantly related to iris colour, especially the grey-brown colouration. This, again, may be a detection effect. The presence of the posterior pupillary membrane or hyaloid system, was not connected with the incidence of persistent pupillary membranes in this survey.

12.23 Acquired Abnormalities of the Uvea.

Only 2 foals had acquired pathological abnormalities and both foals have already been described in other chapters.

Foal 73 was a foal with a septicaemia, due to a Beta haemolytic Streptococcus spp., (see Chapters 4, 5, 7, 8, 10 and 11). It presented at four days post-partum with an acute iridocyclitis of the right eye, a grey-yellow swollen iris, fibrinous hypopyon and fibrin exudate adherent to the anterior surface of the lens and iris, complete unresponsive miosis, and aqueous flare (figure 35). Treatment was instituted. By six days post-partum the hypopyon had increased and changed in nature and colour, and was now yellow, less fibrinous, and up to the pupillary margin. There was 40-50% mydriasis following treatment, and further fibrinous debris on the anterior lens and iris. A severe photophobia, blepharospasm, and lacrimation was present (figure 35). At day eight post-partum the pupil was 50-60% dilated and oval in shape, with less anterior chamber debris and hypopyon. The photophobia and ocular pain had decreased. At day ten post-partum the right eye began to lose ocular pressure, the pupil was 50-60% dilated and of an uneven shape due to extensive posterior synechiae. The eye was blind. The fundus was not visible because of the anterior chamber debris adherent to the lens. At day twelve post-partum there was further loss of pressure with little change in the appearance of the eye. Euthanasia was carried out at day 15 post-partum due to other complications.

Foal 119 was a foal with Neonatal Maladjustment Syndrome and self-inflicted trauma to eyes and body (see Chapters 3, 4, 5, 7, 8, 10, and 11). At day one post-partum the left eye was severely photophobic and visually deficient. There was a swollen grey-green iris and decreased anterior chamber depth, with fresh haemorrhage (hyphaema) attached as a clot to the lower pupillary margin. The pupil was 70% oval, unresponsive to light, with the entire pupillary margin adherent to the anterior lens (Iris Bombé) (figure 39). The posterior segment of the eye was not visible. The right eye was similarly affected with swollen, grey-yellow iris, fibrin debris, and a large haemorrhagic clot on the anterior surface of the iris, especially temporally. There was complete miosis and blindness. The posterior segment of the eye was not visible. The foal died within 24 hours.

Because only 2 cases had acquired abnormalities, no statistical analysis was carried out.

12.3 DISCUSSION.

12.31 Colour and Appearance.

In this survey, the vast majority of foals had a dark brown or grey-brown iris colour, of which 79% had a tan mottling especially towards the periphery. In some of the grey-brown group the mottling was more of a grey colour leading to an iridescent appearance. A more homogenous appearance was occasionally noted, often in the dark brown iris. These findings are very much in accord with Latimer *et al* (1983) and Munroe and Barnett (1984) for the foal and adult. It is usually considered that iris colour and appearance is independent of coat colour in the Thoroughbred and other breeds with whole coloured, non-dilute, hair colours. This survey did not completely agree with this, but the relationship between iris and coat colour was overall rather weak. Specific trends such as the high numbers of grey-brown and grey iris colour in the chestnut and grey horses, and the connection of these groups to iridescent appearance, were more obvious.

The three specific zones of colour in the neonatal iris recognised by Tuchlinski (1935) and quoted by Lavach (1990), were not recognised as such in this survey. Certainly considerable variation within the iris in individuals exists in colour, appearance and surface texture, but it was not obvious to the author that these were regular enough to place in bands or zones.

None of the other shades of iris colour, such as blue and white, were recorded in the survey, but the incidence of these in the Thoroughbred is very low. Two unusual variations of grey iris colour (grey-green/grey-yellow) were seen in the two foals with acute anterior uveitis, which Lavach (1990) has already noted.

In an attempt to establish further the normal ocular pigmentation of different groups of foals, the iris colour was related to other areas of the eye where colour variations occur. The dark brown, mottled iris is more likely to be seen with a pink, black-edged nictitans, whereas the whole pink version is more commonly seen with the lighter iridal colours, and iridescence. When these facts are taken alongside the relationship of coat colour to some parameters, and the connection of iris colour with scleral shelf/pectinate ligament, and ventral corpora nigra incidence, a pattern begins to emerge for certain normal external and anterior segment colourations in the neonatal Thoroughbred foal. These will be discussed in later chapters, as will the apparent relationship of iris colour with a number of fundic colour patterns.

Pupil.

The resting, non-stimulated, pupil in this survey was on average 75%, or three quarters, of the maximum degree of dilation. 50% of neonatal foals appeared to have 80% or greater of their maximal dilation. The resting pupil shape was related to pupil size, and in the young neonate was circular or a broadened oval. Both pupil size and shape depended on the delay in examination time from birth, with the large dilated and circular pupil being the most common in early neonatal life. These findings are in agreement with those already available (Gelatt, 1982; Frauenfelder, 1983; Munroe and Barnett, 1984).

The pupil shape and size, after the stimulation of the pupillary light response, will depend on the efficiency of the PLR. As has already been discussed in the earlier chapter, the PLR in this survey in the young neonatal foal is poor and sluggish/slow. This is confirmed further by the large number of foals with an unchanged pupil shape and minimally changed pupil size, and also by the fairly small change between the mean pupil sizes before and after stimulation. The response to stimulation was also very variable, with a greater spread of sizes afterwards. In general there was a trend of decreasing in degree of dilation by 5-15 points. Stimulation did appear to change the circular shape to mainly oval, with very few foals either pre- or post- PLR having the adult elliptical shape. The change in both pupil size and shape was also dependent on the examination time, with overall a tendency to greater differences in sizes in pre- and post stimulation eyes in older foals, but less obvious evidence of a move to adult shape post stimulation. This would concur with Latimer *et al* (1983) and Frauenfelder (1983) who stated that at 5 days and 3 days respectively, the pupil is generally oval in shape, with a closer to adult resting position than seen in the neonate.

Although no specific measurements of the pupil size were taken in this survey, the generally accepted fact that the nasal portion is slightly wider was noted (Latimer *et al*, 1983).

The effect of the level of ambient light and excitement of the foal, on the resting and stimulated pupil size and shape cannot be judged, but all attempts were made during the examination process to keep foal handling and subsequent disturbance to the foal to a minimum. The pupil and PLR were examined early on and any resistance or excitement was recorded, and taken into account. The level of ambient light was variable because of the variation in the accommodation in which the mare and foals were kept, particularly between the U.K. and New Zealand studs. It is possible that some of the variation in examination light and foal excitement may be reflected in the spread of pupil size and shape, but overall the trends confirm previous work. The overall relationship between foal behaviour and vision with pupil size, is mainly due to the effect of the 4 foals with anisocoria. The correlation of menace reflex and pupil size is probably an effect of examination period, in that both may change towards a normal adult pattern in roughly the same time scale.

Anisocoria.

4 foals were recorded with anisocoria, which is the term used to describe unequal or asymmetrical pupils (Braund, 1987; Scagliotti, 1990). The condition may be caused by a disturbance of the neurological pathways that control pupillary behaviour, or by mechanical or structural problems of the iris. The latter can be congenital or acquired. Congenital causes include aniridia and colobomata, and acquired lesions are iridocyclitis, posterior synechiae, and glaucoma. Some retinal diseases can also affect the pupillary reflex (Braund, 1987). Trauma, infections or vascular lesions of the oculomotor system, retrobulbar area, brainstem, cervical spinal cord, cervical sympathetic trunk, or guttural pouch can cause neurological anisocoria (Mayhew, 1987; Green and Mayhew, 1990). These are also described as static anisocoria, whereas dynamic-contraction anisocoria is used to denote the more extensive direct PLR at the peak of contraction in the stimulated eye as compared to the consensual response (Neer and Carter, 1987). This has already been discussed in Chapter 5 .

With careful and thorough neurological and ophthalmological examination, and a clear understanding of normal pupillary neuroanatomy and behaviour, localisation of the lesion is possible. Precise pinpointing may be accomplished by following a well-defined pharmacologic testing protocol (Scagliotti, 1990).

2 of the foals with anisocoria had iris abnormalities consisting of inflammation and synechiae, with one of these also having neurological signs. The cause of the anisocoria was almost certainly ophthalmic disease in these cases. The foal with Neonatal Maladjustment Syndrome (NMS) had anisocoria at 15 hours after birth (13 hours after the initial convulsive episode) which lasted for about 20 hours. During this time the foal was blind, recumbent and comatose, and had negative PLR and papilloedema (dilated pupil eye). The return of pupil size to

normal balance shadowed the improvement in clinical signs, so that the foal was standing, visual and PLR positive at the same time as the anisocoria had completely disappeared. Anisocoria and blindness are common findings in foals with NMS (Rossdale and Ricketts, 1980). Palmer and Rossdale (1976) reported the neuropathological findings in 18 cases of foals affected with NMS. Cerebral cortical ischaemic necrosis was found in 9 cases, 3 of which also had necrosis of the diencephalon and brain stem. The 9 other affected foals had cerebral, and occasionally brain stem and cerebellar, haemorrhage and/or oedema. The case in this survey recovered and, therefore, pathological confirmation of the site of the lesions is not available. Considering the clinical findings, it appears most likly that the foal in this survey had a cerebral lesion, probably affecting the optic tract, and also some mid-brain involvement.

The other mild case of anisocoria in this survey in an ophthalmologically and neurologically normal foal was thought most likely to be an exaggerated version of the dynamic contraction anisocoria previously mentioned.

Corpora Nigra.

All the foals in this survey had dorsal corpora nigra and 74% had ventral ones. In only one foal were these not bilaterally symmetrical, due in this case to a unilateral uveitis causing shrinkage and distortion. Changes in the corpora are well recorded as an affect of anterior uveitis (Crispin and Matthews, 1987a & b). 95% of the dorsal corpora were of normal size, with only 5 being enlarged and 1 small. The two abnormal corpora were in the unilateral uveitis case described above and a bilateral, traumatically induced, uveitis case. The normal size of the dorsal corpora nigra in the foals in this survey was proportionally smaller than that seen in the adult. The shape of the corpora nigra, both dorsal and ventral, in this survey did vary considerably. No attempt was made to accurately document this but examples of the main types are illustrated.

All dorsal corpora, whatever their size or shape, were prominent and easy to detect. This was not always the case for ventral corpora. The ventral corpora were much smaller than dorsally, and required differentiation from "homogenous exaggeration of the pupillary ruff" (Latimer *et al* 1983) (figures 111 & 112) . The incidence of ventral corpora was much the same in this survey as other published work (Koch *et al*, 1978; Latimer *et al*, 1983) but 25% of foals did not appear to have them. The lower incidence of ventral corpora in the foal compared to the adult may well be a reflection purely of size affecting detection, or development occurring post-natally. The relationship of ventral corpora nigra to pigmentation of other ocular structures is confused in this survey, although the increased numbers seen in the lighter iris colours may be purely related to ease of detection. The masses of corpora-like tissue seen bilaterally on the ventral pupillary border of the iris, whose status and pathology Koch *et al* (1978) had some trouble deciding on, were not recognised and, in fact, were probably ventral corpora.

12.32 Congenital Abnormalities of the Iris.

The low incidence of congenital abnormalities, other than persistent pupillary membranes, is not surprising. Anomalies of pigment are usually in light-coloured breeds and are rare in the Thoroughbred (Priester, 1972; Huston *et al*, 1978). Anterior uveal cysts, particularly those involving the posterior pigment epithelium and corpora nigra are, however, quite common in the Thoroughbred but have not been reported in foals of any age (Latimer and Wyman, 1985).

Persistent Pupillary Membranes.

Initially, the survey concentrated on detecting pupillary membranes of a length greater than the distance from the collarette to the pupillary margin, but none were found. During the later part of the survey it was decided to look at the incidence and character of the commonly recognised collarette tags (Barnett, 1975; Lavach, 1990). 14 foals, or 23% of those examined for these collarettte tags, were positive. In every case, except one, they were short and very small in size, arising from the collarette or mid iris region. All the cases were bilaterally symmetrical. The iris collarette was intermittent in 6 cases, and complete but vestigial in 8. One case was large enough to reach the pupillary edge. No cases of congenital synechiae or transversing of the pupil were found. It is the opinion of the author that the small vestigial persistent pupillary tags seen in young foals, and which can persist into adult life, are unlikely to be abnormal, but merely an incomplete or delayed resorption of a vestigial structure with no pathological significance. In this way they may mimic the hyaloid apparatus, to which they are connected in foetal life. Interestingly, 9 of the 14 foals also had parts of the hyaloid artery and posterior pupillary membrane evident as well, although this was not considered statistically significant.

12.33 Acquired Diseases of the Anterior Uvea Affecting the Neonatal Foal.

Both cases of acquired uveal abnormalities in this survey were inflammatory, or anterior uveitis. The first case was a classical neonatal septicaemia with multiple organ pathology, including ocular changes, pneumonia and septic arthiritis/osteomyelitis/tenosynovitis/myositis. A beta haemolytic Streptococcus spp. was isolated in pure culture from the blood. The foal was confirmed as having inadequate passive transfer of colostral immunoglobulins. Septic uveitis is a commonly occurring part of neonatal bacteraemias/septicaemias, especially where Gram-negative bacteria such as E. coli, Klebsiella spp. and Salmonella spp. are involved (Koterba, 1990). The clinical picture of this case was typical, but a Streptococcus spp. was isolated. However, occasional Gram-positive opportunist pathogens such as Beta haemolytic Streptococcus have been noted as being responsible for some cases of septic uveitis (Rebhun, 1991).

The signs of uveitis appeared very early in this case before other specific organ pathology manifested itself. Rebhun (1991) has suggested that the earliest sign of uveitis in these foals is a change in iris colouration, often to green, but in this case yellow. This is due to fibrin leakage from the iris vasculature.

The typical signs of uveitis appeared in both cases in this survey. Miosis, hypotony, ciliary and conjunctival injection, anterior chamber fibrinous and cellular accumulation, and peripheral corneal vascularisation were clearly evident in foal 73, although, unusually only a single eye was affected. Conversely, both eyes, rather unusually, were involved in the second case which was due to blunt ocular trauma. The vascular uvea has been suggested as the most obvious originator of the traumatic inflammation and, certainly in the case in this survey, the degree of iridal swelling and exudation, particularly fibrin and haemorrhage, was a typical manifestation of such inflammation. The Iris Bombé in the left eye was also a likely effect of the extreme iridal oedema and exudation. The possibility of this case developing the more subacute or chronic changes seen in foal 73 were curtailed by its early demise.

CHAPTER 13.

THE LENS.

13.1 INTRODUCTION AND REVIEW OF LITERATURE.

13.11 Anatomy and Normal Appearance.

The equine lens is biconvex, clear, colourless and asymmetrical. The radius of curvature of its posterior surface is appreciably smaller than that of its anterior surface (Munroe and Barnett, 1984) (figure 115). From an anterior or posterior direction it is a perfect sphere (Barnett and Bedford, 1985). The diameter is 20-22mm, axial length 11-13mm, and volume approximately 3mls, in freshly dissected adult specimens (Gelatt, 1982). Similar measurements for foals are not available. The lens is contained within a strong, weakly elastic capsule, which is thickest at the lens equator to provide adequate attachment for fibres of the suspensory ligament or zonule. These zonular fibres anchor the lens to the ciliary body, and are relatively short in the equine. Further support is provided by attachment to the anterior face of the vitreous body, the lens sitting in a shallow depression (Appendix 2).

Within the lens capsule, the anterior and equatorial surfaces of the lens are covered by a single layer of cuboidal cells, and it is from such cells at the equator that the lens fibres are produced (Barnett and Bedford, 1985). The bulk of the lens is made up of fine hexagonal-shaped fibres bound together. The typical cross-sectional bow is due to migration of the germinal epithelial cells from the periphery to the centre, an act which is also accompanied by a cell body lengthening and loss of nuclear material (figure 115).

Studies of lens embryogenesis in horses have not been performed and information is therefore extracted from data in other species (figures 116 & 117) (Roberts, 1992a). The lens placode develops from the embryonal ectoderm and becomes separated from this layer early on in embryogenesis. This early development influences the arrangement of all other intraocular tissues, and failure of early formation can cause multiple ocular abnormalities. Abnormal formation of the lens vesicle usually results in cataract (Lavach, 1990). The embryonic nucleus of the lens is formed first, consisting of primary lens fibres, to which are added secondary lens fibres from the equatorial region of the anterior epithelial cells. The arrangment of the secondary lens fibres is a very complicated laminated pattern. As they elongate and interlace anteriorly/posteriorly they produce suture lines at their meeting point (foetal nucleus). The cortex is formed next, and continues to develop throughout life as layers are added "onion-like" (figure 115). The hyaloid vasculature (see chapter 14) and the anterior vascular sheath or rete (see Chapter 12) help provide nutrition for the embryonic and foetal lens, with both systems normally atrophying during the later stages of gestation (figure 127).

The examination of the entire lens requires pupillary dilation in the adult eye. However, the neonatal foal, as shown in the previous chapter, has a pupil more circular and nearer maximal dilation than the adult. This allowed the vast majority of examinations of the lens and other deeper structures to be carried out without the use of mydriatics, although the latter were used, when permission was given, where abnormalities were detected. This improved the photographic recording of these structures.

The lens of the neonatal foal is normally completely transparent in appearance (Barnett, 1975), although Lavach (1990) states that the normal neonatal lens may be slightly cloudy, clearing by 1-2 weeks of age. There are marked variations in lens suture patterns among foals and between eyes (Latimer *et al*, 1983), but they are usually obvious (Blogg, 1985), especially with slit-lamp biomicroscopy (Munroe and Barnett, 1984) (figure 14). Generally the anterior suture has a Y configuration, and the posterior one varies from an inverted Y to a sawhorse or stellate pattern with feathering (Kunze, 1983; Latimer *et al*, 1983; Munroe and Barnett, 1984) (figures 118 & 119). Variation within breeds also occurs and in the majority of Thoroughbred foals, the anterior suture is not visualised (Latimer *et al*, 1983; Blogg, 1985).

A structure present in the vitreous body of the foal and attached to the posterior lens capsule is the hyaloid artery. The hyaloid artery, along with the posterior and anterior vascular rete/pupillary membranes, is responsible for supplying nutrition to the developing lens. Both systems are said to atrophy in the later stages of gestation in other species (figure 127). The normal pattern of occurrence, and rate of disappearance, of the equine hyaloid system is recorded in Chapter 14. Barnett (1975) stated that, sometimes, branches of the hyaloid artery may be seen on the posterior capsule (posterior pupillary membrane), and that the hyaloid artery is invariably present. This is usually seen as a fine, dark, curving line transversing the vitreous from optic disc to posterior aspect of the lens. Remnants of the posterior vascular rete, or pupillary membrane, are often observed on the posterior lens capsule during the first 24 hours, but disappear, or are less prominent, in older foals. Koch *et al* (1978) recorded that the remnants of the hyaloid system were present on the posterior pole of the lens of the majority of foals, even up to 30 days old. Latimer *et al* (1983) recorded that 22 out of 144 foals had a prominent anterior hyaloid membrane (7 of which were Thoroughbreds) with an average age of 8.7 weeks. A dot-like axial opacity on the posterior capsule, representing the point of attachment of the hyaloid vessels may remain throughout life, and is called Mittendorf's dot (Lavach, 1990). Only the posterior pupillary membrane or vascular rete will be discussed in this chapter, with the hyaloid artery being reported in Chapter 14.

13.12 Congenital Abnormalities of the Lens.

Cataracts.

The lens reacts to insult by death of cells and lens fibres, abnormal cell proliferation, and disruption in the maintenance of its relatively anhydrous state. Failure of this system allows localised accumulations of water, with resulting vacuolation, and subsequent loss of transparency. The opacity of the lens or its capsule is termed a cataract (Kunze, 1983; Whitley, 1987; Lavach, 1990).

Cataracts can be classified according to the anatomic position of the opacity within the lens (capsular, cortical or nuclear), by degee of maturity, by age of the animal, and by possible cause. They can be unilateral or bilateral, congenital or acquired, primary or secondary to another eye disease, stationary or progressive, and are usually permanent. In a report on congenital ocular defects, cataracts comprised 35% of all defects in the horse (Priester, 1972), although Koch *et al* (1978) and Latimer *et al* (1983) had a much lower incidence: 3 in 82 and 1 in 144 foals examined, respectively. Many authors consider them to be the most commonly reported ocular abnormality of the foal (Latimer and Wyman, 1985; Whitley, 1990; Roberts, 1992a)

Congenital cataracts, by definition, should be present at birth, although Whitley (1990) stated that they may take up to 3 months to manifest themselves. They are often bilateral and the sole defect, but may exist with other problems such as microphthalmia (Whitley, Moore and Slone, 1983), persistent pupillary membranes and hyaloid structures (Latimer and Wyman, 1985), and aniridia (Eriksson, 1955; Joyce, 1983; Joyce *et al*, 1990). The precise aetiology of most congenital cataracts in the horse is unknown. It is implied by the terminology used, that congenital cataracts are due to some sort of insult to the lens between conception and parturition. Possible causes include inheritance (Eriksson, 1955;

Slatter, 1981; Whitley *et al*, 1983), trauma (prenatal and foaling), genetics (Roberts, 1992b), poor nutrition, in-utero infections, exposure to toxic substances, and radiation (Munroe and Barnett, 1984).

Although heredity is difficult to document, a dominant mode of inheritance has been reported in the Belgian (associated with aniridia) (Eriksson, 1955), the Thoroughbred (Slatter, 1981) and Quarterhorse breeds (Joyce *et al*, 1990). Non-progressive, bilateral nuclear cataracts, which have no appreciable affect on vision but have a familial distribution, have also been described in Morgan horses (Beech, Aguirre and Gross, 1984).

Any foal with a congenital cataract should have a good, complete, gestational history taken, and a thorough ophthalmic examination. The foal may present with complaints of visual deficits, clumsiness, or repeated lacerations. The foal should be assessed for vision, other abnormalities, ocular reflexes, and also after mydriasis with 1% tropicamide. This facilitates complete examination of the lens by direct ophthalmoscopy and focal illumination.

Congenital cataracts may involve the lens diffusely or focally. Diffuse cataracts can produce severe visual impairment or blindness. Focal cataracts may involve any area of the lens but are usually small, with a minimal effect on vision. Anterior capsular or cortical opacities can be associated with persistent pupillary membranes that adhere to the lens capsule. These focal opacities may progress to diffuse cortical involvement if the underlying epithelial proliferation and migration are impaired. Cataracts secondary to persistent hyaloid structures are less likely to progress to diffuse cortical involvement, because the lens epithelium does not extend posteriorly beyond the lens equator. They do cause a small concave opacity in the posterior lens capsule (Kunze, 1983). Focal opacities involving the anterior and/or posterior suture lines are often non-progressive (Gelatt, 1982; Walde, 1983b), but progression has been reported (Koch *et al*, 1978). The cause of such an opacity may be increased lens ground substance or reduced lens fibre length. Under magnification they have a vacuolar appearance (Gelatt, 1982).

Focal dense nuclear opacities result from an abnormal influence during foetal or embryonal development (Latimer and Wyman, 1985) (figure 96). They may occur as a solid opacity, a hollow sphere or as concentric irregular rings. Both types may have the periphery of the lens remaining transparent and are not likely to be progressive. The location and extent of a focal opacity will determine its affect on visual function, but often mydriasis, naturally in dim light or artificially with drugs, will improve vision. Vision also improves with age, as new layers of normal cortex increase the total lens size relative to the cataract volume.

Diffuse, mature, cortical cataracts usually cause blindness, which may not become apparent until weaning time due to the close mother/foal relationship. Microphthalmia is present in about 50% of cases (Gelatt, 1982). The dense nature of the cataract prevents examination of the fundus, and the diffuse type prevents mydriasis improving vision. Foals with this type of cataract may be candidates for surgery (Gelatt and Kraft, 1969; Myers and McClure, 1974; Whitley *et al*, 1983; Whitley, Meek, Millichamp, McRae and Priehs, 1990).

Roberts, (1992b) found 33.6% of the foals in his survey (38 foals) had congenital cataracts of which 15 were nuclear, 12 mature, 8 Y suture, and 3 hyaloid-related. Quarter horses and Arabs were the most commonly affected and Thoroughbreds the least. These results may reflect the population of foals examined.

Lens Dislocation or Luxation.

Dislocation or luxation of the lens can be congenital (congenital ectopic lens) or acquired, but both cases are uncommon in the horse (figures 64, 96 & 97). In the foal it is often associated with other congenital anomalies (Brion, 1935; Garner and Griffiths, 1969; Matthews and Hanscombe, 1983b). It is often bilateral, and the primary defect appears to be abnormal zonules in form or number (Wilcock, 1983). The defect is not thought to be inheritable. The lens is often cataractous, and may luxate into the anterior chamber or the vitreous cavity. Anterior luxations may cause marked corneal oedema and, occasionally, glaucoma (Gelatt, 1973). Iridodonesis, a deepened anterior chamber, and an aphakic crescent accompany posterior luxations (Whitley, 1990). Lens extraction is indicated when luxation into the anterior chamber has occurred, provided there are no other ocular anomalies (Latimer and Wyman, 1985).

Lens Coloboma.

Apparent colobomata, or notch-like defects in the horse's equatorial lens, have been reported (Barnett, 1975). These are aften associated with colobomata of the iris and/or ciliary body and absence of zonules in the same region (Latimer and Wyman, 1985). The connection between the various deformities is not known, but failure of moulding traction by the zonules is thought to be important

(Saunders, 1971). Lens colobomas do not significantly impair vision but may predispose to lens subluxation (loss of some zonular attachments, movement of lens, but still present in the patella fossa).

Lenticonus and Lentiglobus.

These are defects in lens shape in which the lens assumes a conical or globular contour, usually affecting the posterior pole. These defects have been reported as sporadic unilateral lesions in the horse (Wilcock, 1983). Visual impairment is determined by the severity of the malformation, and the presence or absence of cataract formation. No treatment is indicated (Whitley, 1990).

Microphakia.

Microphakia (small lens) or aphakia (absence of lens) occur as an isolated defect almost always associated with other abnormalities such as microphthalmia or lens luxation (Trapp, 1957; Wilcock, 1983). True aphakia is only seen in severly malformed, rudimentary eyes. In microphakia the lens equator, zonules and ciliary processes are visible, sometimes with only mild dilation. If it is the only abnormality, it may have no affect on visual function (Latimer and Wyman, 1985).

13.13 Acquired Diseases of the Lens Affecting the Neonatal Foal.

Acquired lens disease in the neonatal foal is rare and restricted to the affects of trauma and inflammation.

Acquired Cataracts.

Whilst these are reasonably common in the adult horse they occur rarely in the neonate, purely because of the short time span available. They occur as sequelae to ocular injury or inflammation. Severe blunt trauma or penetrating eye wounds can lead directly to injury or luxation of the lens, or indirectly, via posterior synechiae and lens capsule disruption (figure 120). The lens capsule injury interferes with its ability to regulate water and electrolyte movement, leading to subsequent vacuole formation, opacity and often permanent and progressive cataract (Moore, 1987).

Cataracts can also occur secondary to uveitis in the septic foal. Posterior synechiae, iris rests, and anterior capsule debris may cause capsular disruption and cataract formation (Moore, 1987). Impaired lens metabolism due to chronic inflammation and altered aqueous humour (iridocyclitis), and cyclitic membrane formation along the posterior lens capsule may lead to further cataractous change (Rebhun, 1991).

Traumatic Lens Luxation.

These follow direct ocular or skull trauma and are rare. They would need to be differentiated from congenital forms.

Lens Rupture.

Blunt trauma to the eye may tear the lens capsule (Severin, 1976) and often in 7-10 days the lens migrates into, and fills, the anterior chamber. The rupture initiates a severe inflammation which may lead to blindness (Lavach, 1990).

13.2 RESULTS AND STATISTICS.

13.21 Anatomy and Appearance.

No abnormalities of size or position of the lens were detected in this survey. All normal lens in this survey were clear and colourless (figures 102 & 104).

Sutures.

Sutures (anterior and/or posterior) were detected in 82% of foals, where the lens was visible on first examination (136 foals) (figures 58, 67 & 71). All cases were bilaterally involved but there was variation between eyes. Sutures were more easily detected by focal illumination (100%) and distant direct ophthalmoscopy, than by direct ophthalmoscopy (9%). Differentiation between the presence of anterior and/or posterior sutures was not attempted, although three foals were confirmed as having both sutures. The shape of the suture varied from a Y to an inverted Y, with occasional more irregular sutures.

There was no relationship of the presence of the lens sutures to foal sex, size, colour or behaviour, the presence of hyaloid artery or posterior pupillary membrane, the examination period, or ocular abnormalities.

Hyaloid Apparatus.

The results relating to this structure in this survey are documented and discussed in Chapter 14, but remnants on the posterior lens capsule were seen in 141 right eyes and 148 left eyes.

Posterior Pupillary Membrane (PPM).

Posterior pupillary membranes (PPMs) or posterior vascular rete were found in 47 left eyes (28%) and 42 right eyes (25%) (figures 98, 107, 121 & 122). 39 foals, of those in which visualisation of the posterior capsule was possible, had bilateral PPMs (23%). The variations in type and extent of the PPM are shown in figure 114.

2 foals had bilateral PPMs that were visible by indirect means (pen torch), as well as by direct ophthalmoscopy. All others were seen on direct close ophthalmoscopy. In 9 foals no diagrams were made because the remnants were so small and/or fine. In the rest, part or the whole of the hyaloid artery was

present, usually attached to the posterior surface of the lens (figures 74 & 122). The only exception is in 64 R eye where only a small remnant was present on the lens. The majority of the PPMs were composed of one or more, fine translucent vessels, or strands, arranged in a variety of patterns (figures 72 & 123). Occasionally, rather than vessels there were collections of debris (figure 107). Some foals had bolder, more obvious remnants (L 72) (figures 121 & 124), and others had collections of debris around the PPM (10, L97, L122) (figure 121). Some remnants moved when the foal moved, especially those with debris (L122) or complicated patterns (L21). The patterns formed ranged from a straight vertical line halfway across the lens (148), to a more lengthened wavy vertical line (84) (figures 58 & 123); one, or occasionally two, wavy structures often running horizontally (71, L41) (figures 98 & 122) or obliquely (14, R8) (figures 57 & 72); Y or X shaped collections of vessels of varying thickness and waviness (19, R109, R81, L21) (figures 106 & 125); more complicated collections in a variety of shapes (R41, R165, R147) (figures 121 & 124). Posterior pupillary membranes appeared not to have a statistically significant relationship with breed, examination period, vision, menace or pupillary reflexes, pupil size, persistent anterior pupillary membranes, L or R sutures, vitreous or other lens abnormalities (see Chapter 14 for the relationship to the hyaloid artery).

13.22 Congenital Abnormalities of the Lens.

In total, 6 foals had lens abnormalities of which 4 were of a congenital type. All of these four were affected by cataractous change in the lens.

Cataracts.

The details of the cataracts found in this survey are described in Table 13.1

Table 13.1

Foal	Behaviour	Parity	Incidence	Opacity	Other Ocular Signs
83	N	U	Bilateral	Small, Discrete, Posterior Capsular assoc. Remnant Hyaloid.	None
99	N	M	Left	Temporal, Posterior Capsular. 40% Visible Lens. Diffuse.	R eye Retinal Haems. Bil. Scleral Haems.
152	N	U	Right	1. Mild, Nuclear. 2. Temporal, Posterior Capsular, adjacent bubbly vacuolation.	Vitreal Debris. Peripapillary Choroidal & RPE Degeneration
164	N	M	Left	Small, Discrete 2 Anterior Capsular black spots.	Atypical Colobomata.

(Figures 103, 106, 126 & 135.)

All 4 foals with cataracts were normal, with no visual deficits or abnormal ocular reflexes. None had any history of gestational or parturition abnormalities. 2 were in uniparous mares, but the 2 multiparous mares had no history of ocular or other congenital abnormalities in previous progeny. All 4 mares were examined ophthalmologically and no abnormalities were found. One foal had retinal and subconjunctival haemorrhages which resolved normally. Another foal had vitreal and fundic lesions which were non-progressive but permanent, and which may have been related to the lens opacity (figures 176 & 188). All 4 cataracts were non-progressive (within the limits of the survey), and did not appear to affect vision at any stage.

13.23 Acquired Abnormalities of the Lens.

2 foals had lens lesions that were considered to have been acquired since birth.

Foal 73 had an acute bacterial neonatal septicaemia. From day 4 onwards there was an acute uveitis of the right eye with a marked hypopyon, miosis, and ocular pain. At day 6 cellular and fibrinous debris was present on the iris and anterior capsule of the lens. At day 8 further debris had been deposited on the lens capsule and the pupil was only 50-60% dilated. By day 10 there was a fixed, partially dilated pupil with posterior synechiae. Debris and pigmented material covered the anterior lens capsule. On day 11 the globe became hypotonic.

Foal 119 had NMS and severe self-inflicted trauma. At examination the foal had a bilateral, severe acute uveitis. The left eye had a hypopyon, hyphaema and fibrin in the anterior chamber, some of which had been deposited on the lens leading to an opacity. There was a complete posterior synechiae and Iris Bombé. The right eye had similiar changes of a lesser degree, with only a partial posterior synechiae(figure 35 & 39).

The two acquired abnormalities were both secondary to acute uveitis, one involving trauma, the other systemic infection. Examination of deeper structures of the eye (to the anterior capsule), including the posterior parts of the lens, was not possible because of the severely constricted, unresponsive pupils and considerable anterior capsular debris. Both foals were blind in affected eyes and had abnormal ocular reflexes. Both died due to systemic illness.

13.3 DISCUSSION.

13.31 Anatomy and Normal Appearance.

The lens of the neonatal foals in this survey were normally completely transparent, although in 50 foals part of the posterior pupillary membrane could be seen on the posterior capsule, very much as described by Barnett (1975). The slight cloudiness mentioned by Lavach (1990) occurring in the neonatal foal was not confirmed.

The suture pattern of the neonatal foal's lens was variable in this survey, as suggested by Latimer *et al* (1983), but 82% of foals had one or both of them visible on first examination. Latimer *et al* (1983) found only 7 of 144 foals had no suture patterns apparent, but in their study a slit light biomicroscope was used. This instrument was not available in this survey and may have been the reason for slightly lower numbers (Munroe and Barnett, 1984). In the foals in this survey focal illumination proved to be the most efficient method of examining the eye for the lens suture pattern (Uberreiter, 1939, in Lavach, 1990), but using this method was not effective in differentiating anterior from posterior sutures. In only 3 foals was the presence of both confirmed, although Latimer *et al* (1983) noted that an inability to visualise the anterior suture of the Thoroughbred foal was common, even with the slit lamp biomicroscope. The shape of the suture pattern varied considerably, although variations on the basic theme of a Y shape were pre-eminent. The variety of configurations shown by Lavach (1990) were not confirmed, probably again because of the limited examination, but also because this variety may be less obvious in neonates. The sparkling peripheral tips, mentioned by Latimer *et al* (1983), Kunze (1983) and Koch *et al* (1983) were not seen. All the foals had bilateral sutures with some, but not extreme, variation between eyes. There was no connection between the presence of the suture pattern and any other parameter, normal or abnormal.

The remnants of the hyaloid apparatus were recorded in 141 right eyes and 148 left eyes. In many of these foals remnants of the posterior pupillary membrane were found. Over 25% of examined foals had remnants, with the majority being bilateral, but not always symmetrical. The variation in type was considerable, although there was generally a confluence towards the lens centre and the origin of the hyaloid artery. There was no relationship to any foal, ocular, or examination parameter, including time since birth. All of them were either clear or very slightly opaque, and none contained blood. Vision did not appear to be affected.

In three cases fibrinous debris was attached to the ghost vessels. This, and some of the remnants themselves, were seen to move with the movement of the foal's head in some cases. Examination of the remnants of the posterior pupillary membrane and differentiation from any abnormality is best achieved using direct ophthalmoscopy, although careful assessment of the position of the structures in relation to the posterior lens capsule and anterior face of the vitreous would be best achieved by the slit lamp biomicroscope. No abnormalities of the lens were found in association with the membrane remnants and it is the opinion of this author that they represent a normal variation, or delay, in the resorption of the foetal lens vascular system. Their subsequent rate and degree of disappearance would require an additional study, but observations made when re-examining foals with retinal haemorrhages suggest it may be slow (see Chapter 14).

13.32 Congenital Abnormalities.

Although Priester (1972), Huston *et al* (1977), Whitley (1990), and Latimer and Wyman (1985) all consider congenital cataracts to be the most commonly reported cause of ocular anomaly in the foal, only 4 cases were recorded in this survey. However, Koch *et al* (1978) and Latimer *et al* (1983) reported an incidence which was much closer to that seen in this survey. No other congenital abnormality of the lens was detected. All 4 cases were associated with other ocular abnormalities, and in only one were the cataracts bilateral. None of the foals had any visual deficits and no evidence of their precise aetiology could be found. The small, posterior capsular, bilateral cataracts associated with hyaloid artery remnants have been recorded in the past (Kunze, 1983; Munroe and Barnett, 1984; Latimer and Wyman, 1985), and rarely progress any further. The unilateral, temporal, posterior, capsular opacity of a diffuse nature seen in one case was not definable in the previously described categories of cataracts in the foal. Its relationship to the subconjunctival and retinal haemorrhages was incidental. The small punctate anterior capsular pigment spots could have been related to remnants of the anterior pupillary membrane (persistent pupillary membrane) but other evidence of this structure was not found (Munroe and Barnett, 1984). The case with mild nuclear and temporal posterior capsular cataracts in the right eye was most interesting because of the associated vitreal and fundic changes. Matthews, Crispin and Parker (1990b) have recorded peripapillary lesions of choroidal and retinal pigment epithelium degeneration in association with diffuse posterior capsular cataracts and vitreal flare. The fundic changes have also been seen in anterior uveitis, no signs of which were seen in this case. However, speculation on the aetiology of this case is possible and it seems likely that the foal was subjected, when in utero, to an insult, possibly an exogenous blood-borne antigen (Williams, Morter, Freeman and Lavignette, 1971), which lead to generalised posterior segment disease and peripapillary choroidal pathology. The nuclear cataract could have developed as a consequence of interrupted lens development in utero. The unilateral changes in the foal of this survey are somewhat surprising considering the earlier theory, but Matthews *et al* (1990b) have reported similar lesions to be usually unilateral.

13.33 Acquired Abnormalities of the Lens.

Acquired cataracts are a common sequelae to ocular injury or inflammation in the adult horse. 2 cases were seen in this survey: one an example of severe ocular inflammation due to a systemic bacterial infection; the other, inflammation due to blunt ocular trauma. Rebhun (1991) suggests that cataract secondary to such severe uveitis may represent one of the most common reasons for blindness in such patients. The cataracts in both these cases, as far as could be determined, were the result of severe anterior capsular debris deposited from the abnormal aqueous humour. Besides the physical obstruction this caused, the resulting injury to the anterior capsule by the debris and extensive posterior synechiae, would certainly have interfered with its ability to regulate the lens water and electrolyte balance (Kunze, 1983). The extraordinary ferocity of the uveitis in the blunt trauma case could have lead one to believe that rupture of the lens might have taken place releasing antigenic material into the eye (Lavach, 1990). Both cases, in contrast to the congenital group of cataracts, were in abnormal foals, with multiple ocular defects and loss of vision.

CHAPTER 14.

THE VITREOUS.

14.1 INTRODUCTION AND REVIEW OF LITERATURE.

14.11 Anatomy and Normal Appearance.

The vitreous body is a clear, semi-fluid gel that occupies the vitreous chamber, the largest compartment of the eye. A concavity on its anterior surface, the patellar (or hyaloid) fossa, is occupied by the lens. The anterior face of the vitreous body is the hyaloid membrane, which is a condensation of vitreal fibrils. There is a circumferential attachment between the lens and the hyaloid membrane, but differentiation from the rest of the posterior lens capsule is poor. The outer peripheral zone of the vitreous is called the cortex, and ventrally is the vitreous base. The latter is intimately attached to the retina. The central portion of the vitreous, and that occupying the hyaloid canal, is more fluid than elsewhere (Lavach, 1990) (figure 128).

The vitreous is approximately 99% water with the gel consistency due to hyaluronic acid. It is relatively acellular and transparent, with low levels of protein.

Prior to closure of the embryonic fissure, a vasoformative mass of mesoderm enters the cavity of the optic cup (figure 127). The most readily recogniseable part of this mesoderm is a branch of the primitive dorsal ophthalmic artery, the hyaloid artery, which traverses the optic cup from the area of the optic disc to the lens (Wilcock, 1983). From the posterior pole of the lens it travels over the surface of the lens in a lace-like pattern to join the anastomotic ring of the annular vessel. From the ring, secondary arcades of vessels over the anterior pole of the lens form the pupillary membrane (anterior tunica vasculosa lentis). The developing lens is thus enveloped in a vascular tunic providing it with nutrition (Saunders, 1971). The vitreous is produced as three types: primary, which develops in the potential space between the embryonic lens and retina and whose major source is the hyaloid vascular system; secondary, which is the vitreous of the adult eye, secreted probably by specific retinal cells; and tertiary, which was the vitreous from which the lens zonules were thought to be formed (Lavach, 1990) (figure 129). Recent research suggests the zonules maybe secreted by the ciliary body non pigmented epithelium.

In a similar way to the pupillary membrane in the anterior chamber, the hyaloid system normally undergoes almost complete atrophy before birth. The proximal and distal extremities are the last to atrophy, being compressed in this direction by the developing secondary vitreous (Wilcock, 1983). Munroe and Barnett (1984) stated that part, or all, of the hyaloid artery is present in all foals under the age of 24 hours. If complete, it can be recognised as a fine, dark, curving line transversing the vitreous from the centre of the optic disc to the posterior aspect of the lens. Remnants may be attached to the lens capsule, e.g. Mittendorf's dot, or originate at the disc (Lavach, 1990). The vessel may contain blood, appear black, or be clear. Remnants of the system are also observed on the posterior lens capsule (posterior pupillary membrane) which tend to run together at the pole of the lens into the hyaloid artery (see Chapter 13). Severin (1976) stated that within a few days, or weeks, the atrophying process is complete, and by 6-9 months most remnants are gone. Others have suggested that blood may still be present in the hyaloid artery in foals of 3 weeks of age (Riis, 1981; Gelatt, 1982; Latimer and Wyman, 1985), or 6-12 weeks (Whitley, 1990). Gelatt (1982) and Wilcock (1983) considered that some incomplete, or complete remnants, may persist into adulthood. In most horses/foals the persistence of the hyaloid vascular system is an incidental and common finding (Barnett, 1975; Koch *et al*, 1978; Latimer *et al*, 1983), not related to any visual disturbance (Whitley, 1990). In a few cases, however, ocular problems can occur (see next section).

14.12 Congenital Abnormalities of the Vitreous.

Persistent Hyaloid Apparatus.

The term persistent hyaloid apparatus (artery) is a relative one in the equine, since, as the previous section has shown, resorption of the system is quite slow, with remnants remaining well into foal life and even adulthood. It is a comparative term derived from human ophthalmology, where the condition causes serious visual defects. Similar problems may occasionally arise in the dog (Saunders and Rubin, 1975). In the horse, persistence of the posterior pupillary membrane and hyaloid artery is usually incidental in otherwise normal foals. Rebhun (1991) did suggest that it was more common in the premature foal.

In those cases where ocular problems exist, a variety of conditions have been recorded. Posterior capsular and subcapsular cataracts, often axial, may arise due to persistence of the hyaloid system, and have already been discussed (figure 135).

They usually appear at the attachment of the hyaloid vessel, are non-progressive, and have a minimal affect on vision (Gelatt, 1982). Uncommonly, a plexus may remain attached to the posterior lens surface, which, if extreme, can cause visual disturbance, without the presence of cataracts (Latimer and Wyman, 1985). If the vessels contain blood, some hyperplastic primary vitreous (PHPV) may persist and cause visual impairment, depending on the extent and density of the fibrovascular membrane, on or near the posterior lens surface (Wilcock, 1983; Whitley, 1990). Vitreous haemorrhage may also occur spontaneously in eyes with persistence of the hyaloid vessels and PHPV, leading to a poor prognosis (Lavach, 1990). Others (Saunders and Rubin, 1975), consider its course may be self limiting, and spontaneous disappearance occurs in several weeks. None of these conditions are thought to be inherited in the horse (Whitley, 1990).

Vitreous Opacities.

Normal opacities of the vitreous include filamentous structures, small "dust-like" specks, and larger floaters (Lavach, 1990). These are considered normal findings in middle-aged and older horses, and originate from cells and protein precipitates associated with vitreal ageing (Rebhun, 1991). However, Errington (1941) found them in 15% of suckling foals and 26% of yearlings. They have not been recorded in the neonate.

14.13 Acquired Abnormalities of the Vitreous.

Vitreous Inflammation.

Vitreous inflammation (hyalitis or vitritis) occurs commonly in uveitis (Gelatt, 1982; Rebhun, 1991). The inflammation brings protein and inflammatory cells into the vitreous from the uveal tract. This leads to a decrease in translucency and a discolouration; clumping of the debris into clouds, filaments or membranous opacities; and diffuse haemorrhage (red/orange haze) or clotted blood (Lavach, 1990; Rebhun, 1991). The vitritis is best diagnosed using distant direct ophthalmoscopy and highlighting vitreal changes against the tapetal background. Treatment is the same as the uveitis but, because of the avascular nature of the vitreous, clearing of the debris etc. is extremely slow and not always complete.

Vitreal Abscesses.

These are rare but are associated with septicaemia in foals (Rebhun, 1991). A dense yellow or white opacity is found in the vitreous, and signs of septic uveitis are also usually present. Endophthalmitis is a common sequel. Resolution of the problem is unlikely, since most of these foals are severely systemically ill and die.

14.2 RESULTS AND STATISTICS.

14.21 Anatomy and Appearance.

166 of the foals in this survey had a vitreous that was clear and translucent, although many of them had remnants of the hyaloid system present. In 2 foals it was not possible to examine the vitreous due to iris abnormalities, and one foal had a vitreal abnormality.

The Hyaloid Artery.

The results of examination of the hyaloid artery in the foals in this survey are shown in Tables 14.1, 14.2, 14.3 and14.4.

Table 14.1 Hyaloid System Incidence.

Right	Left	Bilateral	Left only	Right only
141	148	136	12	5

Table 14.2 Extent of System.

Complete.

Right	Left	Bilateral	Left only	Right only
105	104	94	10	11

Remnants.

Right	Left	Bilateral
36	44	26

Table 14.3 Colour.

	Left	Right
1. Clear	59	59
2. Red	63	62
3. Black	25	19
4. Purple	1	1
Total	148	141

Table 14.4 Character.

	Left	Right
No Pulses, Normal Diameter	48	49
No Pulses, Thin	38	38
Thin	12	13
Thick, No Pulses	3	3
Thick, Twisted	1	1
Thin, Floating	2	1
Detached at lens	6	8
Detached at lens, Floating	2	1
Detached at disc	14	9
Detached at disc, Floating	6	4
Remnant on lens	9	8
Remnant on lens and disc	4	3
Small Remnant at disc	0	1
Remnant on lens and Opacity	1	1

Character

	Left	Right
Detached both ends	1	1
Detached at lens and fractured mid-artery	1	1
Total	148	141

The number of foals with each parameter terminology is shown in Table 14.5

	Left	Right
No Pulses	103	105
Normal Diameter	48	49
Thin	52	52
Thick	4	4
Floating	10	6
Detached at disc	20	13
Detached at lens	8	9
Remnant on lens	9	8
Remnant on lens and disc	4	3
Detached lens and fractured mid-artery	1	0
Remnant lens and Opacity	1	1
Detached both ends	1	1
Twisted	1	1

The most common combinations of colour and character of the hyaloid artery for the left and right eyes in this survey are shown in Table 14.6.

R = right eye

L = left eye

Red, No Pulses, Normal Diameter	29R	30L
Red, No Pulses, Thin	21R	21L
Clear, No Pulses, Thin	28R	26L
Clear, Thin	6R	5L
Black, No Pulses, Normal Diameter	4R	4L
Red, Thin	3R	3L
Clear, Detached at Disc, Floating	4R	6L
Clear, Remnant on Lens	6R	3L
Black, Thin	4R	4L
Clear Detached at Lens	6R	3L
Black, No Pulses, Thin	5R	5L
Red, Thick, No Pulses	3R	3L
Clear, Detached at Disc	5R	10L
Black, Remnant Lens and Opacity	1R	1L
Black, Remnant Lens	1R	6L
Clear, Thin, Floating	1R	1L
Clear, Detached both ends	1R	1L
Red, Remnant Lens	1R	0L
Black, Remnant Lens + Disc	1R	3L

Black, Detached Disc	2R	3L
Red, Detached at Disc	2R	1L
Clear, Small Remnant at Disc	1R	0L
Purple, Remnant Lens + Disc	1R	0L
Clear, Remnant Lens + Disc	1R	2L
Red, Detached at Lens, Floating	1R	2L
Red, Thick, Twisted	1R	1L
Black, Detached at Lens	1R	1L
Red, Thin, Floating	0R	1L
Red, Detached at Lens	1R	2L
Clear, Detached at Lens and Fractured Mid-artery	0R	1L

These can be grouped together as in Table 14.7

<table>
<tr><td colspan="2">Red, No Pulses,
Normal Diameter
L30 R29</td><td colspan="2">Red, No Pulses,
Thin
L24 R24</td><td colspan="2">Red, No Pulses,
Thick
L3 R3</td></tr>
<tr><td></td><td colspan="2">Clear, No Pulses,
Normal Diameter
L14 R16</td><td colspan="2">Clear, No Pulses,
Thin
L17 R18</td><td></td></tr>
<tr><td></td><td colspan="2">Black, No Pulses,
Normal Diameter
L4 R4</td><td colspan="2">Black, No Pulses,
Thin
L9 R9</td><td></td></tr>
</table>

Red, Detached Disc L1 R2	Red, Detached Lens L2 R1	Red, Remnant Lens L0 R1
Clear, Detached Disc L10 R5	Clear, Detached Lens L3 R6	Clear, Remnant Lens L3 R6
Black, Detached Disc L3 R2	Black, Detached Lens L1 R1	Black, Remnant Lens + Opacity L6 R1 L1 R1
Red, Thin, Floating L1 R0	Red, Remnant Lens and Disc L0 R0	Red, Detached Lens Floating L2 R1
Clear, Thin, Floating L1 R1	Clear, Remnant Lens and Disc L2 R1	Clear, Detached Disc Floating L6 R4
Black, Thin, Floating L0 R0	Black, Remnant Lens and Disc L2 R1	
Red, Thick, Twisted No Pulses L1 R1	Purple, Remnant Lens and Disc L0 R1	
Clear, Detached Lens and Disc L1 R1	Clear, Detached Lens and Mid fracture L1 R0	Clear, Small, Remnant Disc L0 R1

The hyaloid system, or remnants thereof, was present in the right eye in 141 foals (83%), and the left eye in 148 foals (87.5%) (figures 47, 74, 130 & 131a). 136 foals (80%) had both eyes with a hyaloid artery, albeit not always of the same type in each eye (figures 74, 131a, 131b & 132). 12 foals had the left eye only with a hyaloid artery, and 5 foals only in the right. The complete system was present in 105 right eyes (62%) and 104 left eyes (61%) (figures 133 & 134).

94 foals (56%) had left and right complete systems, 10 left only and 11 right only. Remnants of the system were present in 36 right eyes (21%) and 44 left eyes (27%) (figures 74 & 135). 26 foals had bilateral remnants of the system.

All hyaloid artery structures were visible by direct ophthalmoscopy, both close and distant. In 7% of foals it was possible to see the hyaloid artery as a faint opacity in the vitreous by focal illumination. These foals all had complete systems, usually either red or black in colour.

The hyaloid colour, which reflects the blood content and degree of denaturation, was recorded and 59 foals had a hyaloid artery which was clear and bloodless (figures 122, 136 & 137). 63 foals had an artery which was red and contained blood (figures 134 & 138) (62 in the right eye), and 1 foal had purple artery remnants. Only in the black colour category was there a significant difference in left and right eyes, 25 and 19 respectively (figures 130 & 139).

The hyaloid system characteristics were recorded, showed considerable variation and, therefore, were split into a large number of groups. No pulsations were seen in any of the arteries, whether they were complete or not. The main categories for the division of hyaloid arteries that were complete, were based on artery diameter. 52 foals (left) and 52 foals (right) had thin arteries (figures 122, 139 & 141) whereas only 4, in both left and right eyes, were described as thick (figures 131a & 131b). Of those remaining with complete systems, 49 foals (right) and 48 foals (left) had an artery diameter considered to be within normal range for the neonatal foal (figures 134 & 140).

The breakdown of the hyaloid system was recorded. Detachment of the hyaloid artery occurred at the optic disc in 20 and 13 foals (left and right eye respectively) (figure 136), whereas only 8 and 9 (left and right eye respectively) were detached at the lens (figure 74). In 1 foal detachment had occurred at both ends at the time of examination. The hyaloid artery was seen to be floating, usually dorsally and ventrally, in 10 left eyes and 6 right eyes (figures 136 & 139). Two of the left eyes and a single right eye still had a complete artery, whereas the others were detached at the lens, disc or both. Remnants of the artery on the lens were reported in 9 and 8 foals (left and right eye respectively) (figure 74), with 1 in each eye leading to an opacity (figure 135). 4 and 3 foals (left and right eye respectively) besides having remnants at the lens, also had them at the optic disc, while only 1 foal (right eye) had solitary optic disc remnants. A single foal had bilaterally twisted arteries (figures 131a & 131b).

The most common combination of colour and character in this survey was red colour with no pulses. 57 foals (left eyes) and 56 foals (right eyes) had this description and all were in the complete category (figure 132). Variation did exist in this combination in the thickness of the artery, with approximately 50% being of normal dimensions (figure 140), and 42% having thin vessel diameter (figure 138). Only 3 foals in this group had thicker than normal artery diameter (figure 131a). The next most frequent combination was clear with no pulsations, which was seen in 31 left eyes and 34 right eyes, with 14 and 17 left eyes, and 16 and 18 right eyes having normal and thin artery diameter, respectively (figures 47 & 142). In addition black with no pulsations was seen in 13 left and 13 right eyes (figures 130 & 139), with 9 left and 9 right eyes, respectively, also being thin. All of these combinations were seen in complete hyaloid arteries.

In those foals where there was a breakdown of the hyaloid artery system, the most common combination was detachment at the disc with a clear colouration (16 left and 9 right eyes), with 6 left and 4 right eyes also having the detached vessel floating in the vitreous. Only 1 left and 2 right eyes had red colour/detached disc and 3 left/2 right eyes with black colour/detached disc. Detachment at the lens occurred less frequently and the association with colour was less clear cut. 4 left and 2 right, 3 left and 6 right, and 1 left and 1 right, being red, clear, and black with detached at lens, respectively. Detachment at more than one point at a time was rare, with only 1 foal having detachment at the lens and disc, and 1 foal detached at the lens and fractured mid-artery. After detachment, remnants were found quite commonly on the lens (9 left and 8 right eyes) (figures 74 & 135), and an additional 4 left and 3 right had remnants on the lens and disc. Only 1 foal had just a small remnant on the disc. The vast majority of remnants were either clear (figure 74) (5 left and 8 right) or black (9 left and 4 right).

Statistical analysis was carried out on the results. Although dissimilarities do exist between left and right eyes in the data, statistically there is a very strong relationship between the eyes in, the presence of the hyaloid artery or remnants thereof, its completeness, colour, character, and visualisation by direct ophthalmoscopy. There is a significant association between left hyaloid colour and character, and similarly in the right eye. The most statistically significant specific relationships between colour and character are: clear colour and detached disc +/- floating; clear colour and detached at the lens; red colour and no pulses +/- thin/normal diameter; black colour and remnant on the lens +/- disc; and black colour with a thin diameter complete artery.

The presence of a hyaloid artery or remnant was found to be significantly related to breed, foal behaviour, examination period, vision, pupillary light reflex and rapidity; pupil size, and posterior pupillary membrane. Complete hyaloid arteries were statistically correlated with the same, except pupillary reflexes and size. Hyaloid colour and character were similarly statistically related to examination period, vision, pupil size and posterior pupillary membrane.

14.22 Congenital Abnormalities of the Vitreous.

Persistent hyaloid arteries have already been reported in 14.21. Of the 3 abnormalities detected in the vitreous in the foals in this survey, only one was of congenital origin. Foal 152 (see Chapters 13 and 15) had a lens and fundic abnormality in the right eye which was associated with a vitreal opacity. The vitreal lesion consisted of fine sheets of opaque material, possibly fibrinous debris, which moved within the vitreous on foal head movement. These had partially resolved on later examinations, although the other ocular lesions did not.

14.23 Acquired Lesions of the Vitreous Affecting Foals.

2 foals in this survey were classed as having abnormal vitreous, because in both it was not visible. This was due to severe pathology, especially involving the uvea, anterior to the vitreous (foals 73, 119).

14.3 DISCUSSION.

14.31 Normal Anatomy and Appearance.

The normal appearance of the vitreous in the neonatal foal appears to be as in the adult, namely colourless and translucent, with the exception of the presence of the hyaloid artery or remnants.

Hyaloid Artery.

The hyaloid artery, either complete or remnants thereof, was present in the vast majority of foals in this survey. This confirms the view of other authors who conducted similar surveys, albeit in older foals. Koch *et al* (1978) found remnants of the system, especially on the posterior pole of the lens, in the vast majority of foals up to the age of 30 days. Over 80% of foals in this survey had some part of the hyaloid artery present bilaterally. The presence of the structure in one eye is likely to mean that it will also be found in the other eye. Furthermore, the degree of completeness, colour and character of the system is statistically likely to be similar. The unilateral incidence of the hyaloid artery in this survey was low, but did appear to be related to the examination period and, therefore, the length of time for resolution of the system. Small differences in rate and type of regression may have lead to one side disappearing before the other. The complete artery was present in just over 60% of foals, with approximately 90% being of bilateral incidence.

The number of foals with some, or all, of the hyaloid artery present was found to be statistically lower in New Zealand bred horses, which may have been due to population differences in rate of regression, or greater delay in examination period. Statistically, however, there was no difference in examination periods between the countries. Foal birth weight and maturity might be factors as Rebhun (1991) did suggest that prematurity might lead to a higher incidence of persistent hyaloid structures. Although birth weights in the New Zealand foals were significantly higher, overall there was no relationship in this survey between foal birth weight and the presence of a hyaloid artery. Foal behaviour was related to the presence of the hyaloid system. This relationship was, however, more associated with a lack of visualisation of the system due to other ophthalmic abnormalities seen in abnormal foals. There was no confirmation of the increased presence of the hyaloid system in premature/dysmature foals in this survey.

The difference between the two populations of foals does not have an obvious explanation.

The examination period was related to the incidence of the hyaloid artery and its completeness, colour and character. The vast majority of foals with a hyaloid artery were seen in the first 48 hours, and during this period it is more likely that the structure would be complete. This would seem to confirm the view of Munroe and Barnett (1984) who stated that part or all of the hyaloid system is present in all foals under 24 hours old. They and Severin (1976) stated that regression starts prenatally and that the atrophying process is complete in a few days or weeks. It appears from this survey's results that the atrophying process leading to physical breaking up or detachment of the artery, is still in the early stages by 2 days of age.

The very high incidence of so-called persistent hyaloid structures, including the posterior pupillary membrane, to which it is physically and statistically related, in this survey tends to support the idea that in the foal, unlike the human (from which the term was initially derived), the resolution of the embryonic and foetal system normally carries on into the neonatal period. The presence, therefore, of any hyaloid artery structure in the neonatal period is not an indication of abnormality itself, although careful evaluation to confirm the normal appearance would be prudent. This philosophy has already been suggested by Gelatt (1982) and Latimer and Wyman (1985). Although statistical analysis suggested that vision and the presence/absence of the hyaloid artery were related, this was due to the inability to visualise the structure in some of the blind foals because of severe anterior eye problems. If these foals are removed from the statistical calculations, this survey can confirm that hyaloid artery structures do not generally cause ocular problems. This is further confirmed by the relationship of the presence of the hyaloid artery to the pupillary light reflex and pupil size, already suggested in Chapter 5 to be normal for the neonatal foal. This statistical correlation is almost certainly related to the examination period affect on both entities' normal development/resolution.

37% of foals in this survey had a hyaloid artery with blood in (red), although a further 25 and 19 foals had black material, possibly denatured blood, in their left and right eyes, respectively. Although red was the biggest category in the colour grouping, it does seem unlikely that very many foals will still have blood in their hyaloid arteries as late as some authors have suggested (Latimer and Wyman, 1985; Whitley, 1990). Indeed, in this survey, the colour of the hyaloid system was related to examination time, with a higher incidence of red vessels in the first 24 hours, and clear structures in the 24-48 hour period. Only 1 foal had blood in the hyaloid artery after 48 hours. Colour and character of the hyaloid system are related, and changes in the latter are also correlated with examination time. Complete systems, which have a higher incidence of red colouration, are more common in the early examination period (<24 hours) and, as the system starts to breakdown, the change in colour mirrors the extent of disruption seen at various examination periods. Thus foals with detachments or remnants of the artery have a lower number of the red, blood-filled colour.

Some authors have suggested that pulsations may be seen in the complete hyaloid system in some neonates (Gelatt, 1982), but others (Frauenfelder, 1983) have stated that as early as 2 hours after birth no blood or pulsations may be observed within the artery. In this survey, none of the arteries whatever their colour, had any pulsations present at any stage of the examination period. It seems most likely that the blood is stagnant and trapped in the non-functional artery, before denaturation and/or resorption by the body, removes it. In those arteries or remnants that are clear, it is presumed that all blood cells and their breakdown products have been removed prior to detachment, although in a few foals the remnants of the artery were still red. Statistically, the relationship between colour and character in this survey tends to support the view of a co-ordinated absorption/removal of blood alongside breakdown of the vascular system. Clear vessels were strongly correlated with detachment at the disc and/or lens, whereas red colour was much more common in complete vessels. The relationship of black colour with remnants on the lens and/or disc is probably an optical effect of having a small compact structure interrupting the passage of light, usually at the level of the lens, rather more obviously than a long fine artery within the vitreous.

The complete hyaloid arteries in this survey were seen as fine, curving vessels traversing the vitreous from the centre of the optic disc to the posterior aspect of the lens. Besides their colour, an assessment was made of their diameter. 48 left and 49 right eyes had a diameter of vessel that was considered normal for neonatal foals. 52 foals, however, had vessels that were described as thinner than normal. This may have been due to removal of blood cells allowing contraction of the vessel, as seen in the shift in proportion of the numbers of red to clear vessels in this category. More likely is the compression in mid-artery by the developing secondary vitreous (Wilcock, 1983), which encourages thinning and atrophy at this point. Presumeably, also, the vessel atrophies and thins as it undergoes spontaneous degeneration. Those few arteries that were described as thickened, were all full of blood, and in one case also twisted. It seems that these represented vessels earlier in their regression phase and more like those in the foetal period, with larger diameter patent vessels and increased blood content.

The pattern of breakdown has been suggested by Wilcock (1983) to occur in the middle of the artery with the proximal and distal extremities the last to atrophy. The pattern in this survey was slightly different to this and more confused. Detachment at the optic disc occurred more commonly than that at the lens but, when both categories are put together, it appears that 62% of non-complete hyaloid systems detached initially at one or more of these sites. One additional foal managed to have detachment at both ends and still have an artery visible in the vitreous. Many of the detached arteries were also seen to "float" in the vitreous. Thus, as the foal moved its eye or head, the vessel, especially towards its distal detached portion, floated dorsally and ventrally. This was also seen in a few complete arteries which were described as thin. It was postulated that this was related to increased length of the atrophying and compressed vessel allowing enough slack for movement. It is thought that the movement occurs in the more fluid vitreous of the hyaloid canal (Lavach, 1990).

It appears from this survey that detachment at lens and/or disc often occurs before atrophy of the central section, and that remnants may be left behind if the point of detachment is not immediately adjacent to the lens or disc. In a few cases the remnants were long enough to confirm that atrophy and detachment had occurred away from either end. Remnants of the artery on the lens were much more common than those at the disc, and in only one foal was an optic disc remnant alone found. Similar results were recorded by Latimer *et al* (1983) in older foals (5 days - 16 weeks). Some of the lens remnants were small and would be classified as Mittendorf's dot, but others were longer. These were presumeably likely to atrophy further towards, or to detach at, the lens later on in the foal's life.

The presence of a posterior pupillary membrane was strongly correlated with the presence, completeness, colour, and character of the hyaloid artery. This relationship is to be expected considering, in reality, the posterior pupillary membrane and hyaloid artery are one system, and any division is purely for descriptive, anatomical purposes. In all foals, except 3 in the right eye, the posterior pupillary membrane did not occur without hyaloid artery remnants. In the 3 right eyes in which they did, the posterior pupillary membrane remnants were very small. 81% of foals with a posterior pupillary membrane had a complete hyaloid system. There was a significant relationship between the PPM and red/black hyaloid artery colour. The type of PPM seen with a red artery, usually complete, was in general more extensive than that seen with the black, usually incomplete, hyaloid remnant. The pattern of occurence and removal/breakdown of the PPM in this survey appeared to mirror that seen in the hyaloid artery, although the relationship of this to time was less obvious than in the latter. In general, if an extensive PPM was seen, it was associated with a complete, red hyaloid artery, whereas less extensive or small remants were likely to be related to a black, incomplete artery, especially a lens remnant. The pattern of breakdown of the PPM was not obvious from this survey although subjectively it appeared to occur initially at the connection to the hyaloid artery and spread centrifugally towards the lens equator.

14.32 Congenital Abnormalities of the Vitreous.

Persistent Hyaloid Apparatus.

Since the previous discussion has proved that in the neonatal foal, the complete or regressing hyaloid artery (and its related component, the posterior pupillary membrane), are a normal incidental finding, the persistent term is difficult to apply to this age of foal. This is further confirmed by the low incidence of abnormalities related to persistence of the hyaloid system found in this survey, despite the high percentage of foals with complete, or parts of, the artery and posterior pupillary membrane. Only one foal had a related abnormality: a bilateral capsular cataract that was discussed in Chapter 13. None of the foals with vestiges of the system appeared to have vitreal haemorrhage despite some foals having detached arteries with red colouration, presumeably due to red blood cells. No cases of persistent hyperplastic primary vitreous (PHPV) were recorded, although the foals were very young in this survey. Wilcock (1983) has already stated that he considers PHPV, which is a human condition, to have no counterpart in domestic animals.

Vitreal Opacities.

One foal in this survey had a congenital vitreal opacity in association with significant lens and fundic pathology. This case has been discussed in chapter 13, but worth highlighting here is the fact that the vitreal lesions suggest the problem involved a generalised posterior segment inflammation, rather than specific affects on the lens or retina. The changes seen were reminiscent of those recorded in some cases of recurrent uveitis, although, in this foal they were less severe and no iris abnormalities were detected.

No other vitreal opacities were detected in this survey and it was not possible to confirm Errington's (1941) earlier work. These results were, however, in older foals and make comparision a little tenuous. In the author's experience most vitreal opacities of a non pathological nature are in older adults.

14.33 Acquired Abnormalities of the Vitreous.

None of the foals in this survey had any evidence of acquired vitreal abnormalities, although the congenital vitreal opacity already described was presumeably acquired as a foetus, through vitreal inflammation. In those foals where the vitreous was not visible due to severe anterior segment changes, it was not possible to confirm the presence of vitreal damage as part of the severe uveal inflammation.

CHAPTER 15.

THE FUNDUS.

15.1 INTRODUCTION AND REVIEW OF LITERATURE.

15.11 Anatomy and Normal Appearance.

The ocular fundus of the horse consists of an optic disc or papilla, retinal blood vessels, tapetum lucidum or tapetal fundus, and the tapetum nigrum or non-tapetal fundus (Barnett, 1972) (figures 15, 137 & 196). The fundus contains the neurosensory retina, which is a complex structure where light energy is converted into electrical and chemical energy, the signal so generated being transmitted to the visual cortex of the brain by the optic nerve fibres (Barnett and Bedford, 1985). The relationship of the retina to the other structures in the fundus is complex, and is important for its well being. A basic knowledge of the embryology of the posterior half of the eye is essential to understand both normal anatomy, anomalies, and pathological variations.

Embryology.

The development of the equine fundus has been described by Crispin *et al* (1990) although, as no specific literature is available on the detailed embryology of the equine eye, some of the aspects are based on comparative work in other species (figure 116).

The retina develops from the neural ectoderm, the choroid and sclera from the mesoderm. During embryogenesis the presumptive retina evaginates as the optic vesicle from the anterior part of the neural groove. This then becomes indented to form the optic cup, which is a double layer of neural ectoderm connected to the forebrain by the optic stalk. This cup, initially, has a ventral notch in the double wall which is termed the optic (foetal, choroidal) fissure. This eventually closes and completes the double-walled cup. The neuroretina develops from the inner layer of the cup, with their associated nerve fibres reaching the brain via the lumen of the optic stalk. The outer layer of the optic cup is the future, single-layered, retinal pigment epithelium (RPE).

During embryogenesis, the mesenchyme adjacent to the optic cup develops into two accessory coats. The outer coat is the fibrous sclera, and the inner differentiates into the uvea tract, which includes the choroid. The choroid, which is a vascular layer, is located between the sclera and the retinal pigment epithelium. In the majority of horses, a fibrous tapetum develops in the choroid and acts as a reflective layer.

Structure.

The horse has a typical mammalian retina consisting of 10 layers (Lavach, 1990) (figure 28), with the neuroepithelial photoreceptor cells linked with bipolar and ganglion cells to form a pathway to the retinal nerve fibres (figures 143, 144 & 145). As well as vertical pathways, there are lateral links via the horizontal and amacrine cells. Supporting cells, including Müller cells, are also present (Crispin *et al*, 1990). Rods and cones make up the photoreceptors in the ratio of approximately 20:1 in the horse (Wouters and De Moor, 1979). Two macular areas, where there is a proposed abundance of cones, have been described in the equine (Prince *et al*, 1960, cited by Crispin *et al*, 1990), although a true macula is said not to exist (Lavach, 1990). These areas are termed the visual streak and the area centralis, and both are located dorso-lateral to the optic disc within the tapetal fundus. The neural retina terminates near the ciliary body at the ora ciliaris retina, with the ora being 5mm further from the iris root both nasally and temporally (Lavach, 1990). This protrusion nasally provides a wide visual field in the obliquely horizontal meridian.

The retinal pigment epithelium is a single layer of cells around the outer circumference of the retina (figures 28 & 145). The outer segments of the photoreceptors are surrounded by villi-like prolongations of the apical cell membrane of the pigment epithelium (Crispin *et al*, 1990). The basal cell membrane of the pigment epithelium has complex infoldings along its length which are designed to aid active absorption of nutrients from the choriocapillaris. The retinal pigment epithelium is an important part of the blood retinal barrier, and normal retinal nutrition and metabolism.

The choroid is the posterior uvea, providing nutrition to the posterior segment of the eye (figure 143). From the outermost layer inward, it is anatomically divided into the following: the lamina fusca, which is the junction between choroid and sclera; the suprachoroidea, the heavily pigmented outer layer; the choroidal stroma, which is richly vascularised in loose, pigmented, connective tissue; the tapetum; the choriocapillaris, the thin layer of fenestrated capillaries derived from the arterioles of the choroidal stroma; and, finally, Bruch's membrane, which is a poorly developed, elastic membrane between the retinal pigment epithelium and choroid (Crispin *et al*, 1990; Lavach, 1990).

The tapetum is made up of collagen fibrils, with a constant diameter and regular spatial arrangement, that are orientated parallel to the retinal surface (figure 144). The tapetum, because of its fibrillar nature, protects the overlying retina from pathological changes within the deeper choroidal layers. Its primary purpose, however, is to reflect light back to the photoreceptors, so increasing their stimulation and accentuation of luminosity, but also resulting in a loss of visual acuity (Crispin *et al*, 1990). The retinal pigment epithelium overlying the tapetum contains less melanin pigment granules than the non-tapetal area (figures 144 & 145). The tapetum occupies about two thirds of the dorsal ocular fundus, in an approximately triangular shape, above the optic papilla (figure 196). The lower limit of the tapetal area with the non-tapetal fundus is distinct and marked by a horizontal border (figure 137). Towards the periphery of the tapetal area the structure thins and is interspersed by pigment cells (figure 146).

The optic nerve is formed by the axons of the ganglion cells of the retina and begins at the optic disc (papilla) (figure 137 and 196). This is where the axons join together and exit through the lamina cribosa sclerae. The optic disc is detected by the ophthalmoscope within the non-tapetal fundus, slightly temporal to the visual axis. The pale appearance of the disc is associated with components of the optic nerve behind the lamina cribosa, especially the connective tissue and the myelin sheaths. Redness is related to retinal vessels and the papillary capillary vessels.

The fundus of the horse is paurangiotic (poorly vascularised), with 40-60 small retinal vessels (arterioles/venules cannot be differentiated) radiating from the optic disc (figures 15 & 147). They extend one or two disc diameters horizontally, less dorsally and ventrally (especially in the region of the embryological fissure), and branch dichotomously. The vessels are present only as deep as the retinal nerve fibre layer (De Schaepdrijver, Simeons, Lauwers and De Geest, 1989) and, therefore, except in the immediate region around the disc, the retina in the horse is avascular.

The Stars of Winslow are small choroidal vessels that penetrate the tapetum and are viewed end on (figure 148). They are a characteristic of the equine fundus. The neuroretina is transparent and, therefore, the colour of the fundus is determined by the level of pigmentation in the retinal pigment epithelium and choroid, and also the presence/absence of a tapetum (figures 144 & 145). Choroidal vessels may be visible if the pigmentation is decreased and the tapetum absent (figure 149).

Normal Appearance.

The ocular fundus of the horse is most easily examined by close direct ophthalmoscopy (figure 9). The discussion of the normal appearance will be split into optic disc (papilla), retinal vessels, tapetal fundus, and non-tapetal fundus. The fundus appearance in the foal is said to be similar to the adult (Latimer and Wyman, 1985).

Optic Disc.

The optic nerve head is situated in the non-tapetal fundus and is usually oval (figures 149, 150 & 196), although round, flattened ellipse, nasally blunted, and "rugby football-shaped" have been recorded (Latimer *et al*, 1983; Munroe and Barnett, 1984; Barnett and Bedford, 1985; Matthews *et al*, 1990a). Lavach (1990) stated that young horses have round discs with smooth margins, whereas older horses have an oblate spheroid disc with irregular margins. Optic disc colour in the foal is usually consistent between the two eyes and changes with age (figures 149 & 150). The colour within the first 24 hours can vary between pale pink and deep red. As the foal ages, the disc becomes lighter (pale pink to salmon pink) with a darker border (Munroe and Barnett, 1984). Latimer *et al* (1983) noticed some discs' surfaces appeared fasciculated, but this was in older foals. These may take on a more fibrous appearance in later life (Riis, 1981; Gelatt, 1982) (figure 149). A white rim may be present along the mid-ventral aspect of the disc where retinal vessels are least numerous (Munroe and Barnett, 1984; Latimer and Wyman, 1985) (figure 151). Matthews *et al* (1990a) noted that a distinct notch may be present on the ventral margin of the disc along the plane of the embryonic optic fissure. Latimer *et al* (1983), in their survey, also found the margins of the disc to be pigmented in a number of foals (see non-tapetal section). The physiological cup is inapparent or shallow in most foals.

Retinal Vasculature.

As already stated, some 40-60 small retinal vessels radiate from the optic disc in all directions, with fewer emerging in the mid-ventral region (Gelatt, 1982; Latimer *et al*, 1983; Munroe and Barnett, 1984) (figure 147). Arterioles and venules cannot be differentiated (Rubin, 1974). The vessels traverse the retina 1 to 2.5 disc diameters from the disc margin in approximately straight lines (Latimer and Wyman, 1985), although some tortuosity can occur (Barnett and Bedford, 1985). Occasionally, a single tortuous or bifurcating blood vessel may be seen to course over the surface of the disc (Munroe and Barnett, 1984; Matthews *et al*, 1990a) (figure 152). A slight rim at the periphery of the disc raises the retinal vessels as they traverse it from 1-2 mm inside it (Lavach, 1990). A commonly observed feature of the non-tapetal fundus are light grey streaks arcing nasally and temporally away from the ventral disc margin, following the course of the retinal vessels in these areas. Latimer and Wyman (1985) thought they were due to altered reflectivity of the nerve fibre layer or subtle myelin extension into the nerve fibre layer. Lavach (1990) and Matthews *et al* (1990a) considered them to be extensions of myelin sheaths, for a varying distance into the peripapillary fundus from the lamina cribosa, although the structures are considerably more prominent in the study by Matthews *et al* (1990a) than in Latimer *et al* (1983), and may be different structures.

The Tapetal Fundus.

The tapetal fundus is visible in most foals above the optic disc in an approximately triangular shape of variable size (figure 196). Tapetal colour on ophthalmoscopy varies considerably, but does appear to be related to coat colour (Munroe and Barnett, 1984; Matthews *et al*, 1990a; Rebhun, 1991). The predominent colour in one survey of foals was green (Latimer *et al*, 1983), but variations include primary yellow, nasal yellow with temporal green, green with a yellow periphery, yellow-green, and yellow with green islands (Latimer *et al*, 1983; Munroe and Barnett, 1984). Foals with cream and light-coloured hair coats may have more yellow in the tapetal fundus (figure 99), whereas chestnut or bay horses can be yellow-green (figure 148), and black or grey animals a slightly more bluish colouration (Munroe and Barnett, 1984) (figure 153). The blue-green tapetal colouration commonly observed in the adult horse is less common in the foal, and is thought to result from tapetal maturation with age. In certain breeds and individuals, the tapetal colour varies from one area to another with a relatively well-defined junction between areas (Latimer *et al*, 1983). Pigment mottling occurs commonly in the dorsal and peripheral tapetal fundus, especially nasally, and is related to thinning of the tapetum and penetration by pigment epithelium (figures 15 & 146).

Penetration of the tapetum by small choroidal vessels appears as brown or black dots (the Stars of Winslow), distributed throughout the tapetal fundus (Munroe and Barnett, 1984). The colour of the Stars of Winslow vary with tapetal colour (Gelatt, 1969; Rebhun, 1991), and are especially visible in individuals with light tapetal fundi (figure 154).

Colour dilute (subalbinotic) and albino horses frequently lack a tapetum, or have only portions of it present. In the tapetal fundus the colouration is light yellow, with red Stars of Winslow. If partially present, the tapetal zones will be distinctly demarcated from the albinotic fundus (Gelatt, 1982). In extreme cases, where no tapetum or pigment is present, the choroidal vessels draining into the vortex veins, are seen against a pale cream background (sclera) (Crispin *et al*, 1990) (figure 99).

The junction between the tapetal and non-tapetal areas of the fundus is usually prominent in foals, and may be straight or ragged in appearance (Munroe and Barnett, 1984) (figures 155, 156 & 196). In the majority of foals, the ventral extent of the tapetum is approximately one quarter disc diameter dorsal to the optic disc. In some foals, however, the tapetum dips ventrally toward, or to, the dorsal margin of the optic disc (Latimer *et al*, 1983). In this area the colouration may be different from the overall tapetal colour (figure 157).

Focal atapetal areas can occur and present as discrete, reddish-brown spots in the central area of the tapetal fundus. Tapetal "islands" have been seen in foals as dense green circumscribed areas in the tapetal fundus (Latimer *et al*, 1983) (figure 158). These require to be differentiated from isolated foci of a bluish purple appearance commonly seen in the tapetal fundus, especially of grey horses. Matthews *et al* (1990a) suggest they may be due to minor anomalies of blood vessels within the choriocapillaris.

Choroidal vessels extending dorsally from the disc have been commonly observed in foals in areas of pink or red streaks of variable width and length (Latimer *et al*, 1983). This choroidal vasculature is seen because of a relative thinning, or hypoplasia, of the tapetum and accompanying local or generalised dilution of retinal pigment in the non-tapetal fundus in certain areas (Matthews *et al*, 1990a) (figures 149 & 159). The most common area to be so affected is the suprapapillary area at the junction of the tapetal and non-tapetal fundus. Discrete choroidal vessels are occasionally seen within the hypopigmented region adjacent to the disc. The choroidal patterns can extend as far as five disc diameters into the tapetal fundus, and vary in width from narrow bands to the full breadth of the disc. The choroidal vessels or "streaks" are not always contiguous with the disc, occasionally take "halo" or irregular shapes, and in some foals extend ventrally into the non-tapetal fundus (Latimer *et al*, 1983). Barnett (1972) described an occasional finding of convergent bluish striae and spots in the tapetal fundus due to localised tapetal thinning along the vortex veins (figures 137 & 198).

Altered colouration in the peripheral fundus can also be explained by a lack of tapetum and/or pigment (Rubin, 1974; Koch *et al*, 1978). These may affect the entire fundus or large segments of it, exposing the choroidal vasculature and underlying sclera (figure 199). Differentiation of these colour alterations from areas of coloboma or acquired lesions, requires careful examination. Linear or focal areas of intense pigmentation may be observed in the RPE close to the periphery of the tapetal fundus in the otherwise normal eye (Matthews *et al*, 1990a).

The Non-tapetal Fundus.

In the majority of foals, the non-tapetal fundus is a dark brown or chocolate colour, but occasionally a reddish-brown, or even orange, has been reported in lightly pigmented horses (Latimer *et al*, 1983) (figure 156). Subalbinism and albinism can involve the non-tapetal fundus with appearances varying from a diffuse red-brown colour in mild cases, to complete loss of pigment and full view of choroidal vessels (figure 99). The light grey streaks, probably related to myelin extension, seen in the ventral peripapillary area of the non-tapetal fundus have already been discussed. Similarly, the dorsal peripapillary area with decreased pigmentation, red or pink streaks, and choroidal vessels, have also been described previously.

Narrow zones of intense pigmentation may be observed in the peripapillary non-tapetal fundus adjacent to the inferior papillary border, especially in the subalbinotic fundi (figure 160). These pigment zones extend laterally and medially along the disc margin. They are regarded as a consequence of aberrant local differentiation of the outer layer of the embryonic optic cup, the precursor of the RPE (Matthews *et al*, 1990a). Less commonly, scattered focal areas of RPE depigmentation and choroidal aplasia may occur in the peripapillary fundus, immediately inferior to the optic disc, and in association with peripapillary hyperpigmentation. Matthews *et al* (1990a) consider them to be of congenital origin.

A common pigmentary variant is a narrow zone of sparsely pigmented RPE around the periphery of the optic disc. This extends for a variable distance around the disc, but never includes the inferior pole of the disc in the area of the optic fissure (figure 149).

Tapetal islands, which are small areas of tapetal structure present in the non-tapetal fundus have been recorded in the foal's eye in the peripapillary area (Gelatt, 1982; Latimer *et al*, 1983). They are visible as a result of reduced pigmentation in these areas (figure 160).

15.12 Congenital Abnormalities of the Fundus.

The incidence of congenital fundic lesions is low (Munroe and Barnett, 1984), but variations in the equine ocular fundus are numerous, as has been described in the last section. Differentiation of the two is not always easy.

Colobomata of the Fundus.

In general, colobomata of the equine fundus may be divided into two categories, typical and atypical, according to their anatomical relationship with the embryonic optic fissure (Matthews *et al*, 1990a). They are usually unilateral, and are not thought to be inherited in the horse.

Typical, or true, colobomata are rare and arise due to imperfect closure of the optic fissure in the embryonic eye (Wilcock, 1983). They are located along a plane extending vertically into the non-tapetal fundus from the inferior pole of the optic disc. In severe cases the problem is bilateral and the foal is blind with a searching nystagmus (Wheeler and Collier, 1990). The colobomata may involve any of the structures of the posterior segment, either singly or collectively. In severe cases, the fundus may be albinotic or subalbinotic, and have signs suggestive of retinal dysplasia and/or detachment (Lavach, 1990). True colobomata, with severe neuroectodermal inversion, may result in retrobulbar cysts or cystic eyes (Wilcock, 1983; Schuh, 1989). In less severe cases, there may be absence of normal RPE and choroid, but the presence of retinal vessels within the defect is common and, therefore, not a useful indicator for the inclusion of the normal neurosensory retina within the coloboma (Matthews *et al*, 1990a).

Atypical colobomata are more frequently found (Szutter, 1962; Rubin, 1974; Koch *et al*, 1978; Rebhun, 1983 and 1992), and are considered to be fundic variants or incidental findings by some authors (Rebhun, 1983; Matthews *et al*, 1990a) (figure 149). They are found within the non-tapetal fundus either peripapillary (Matthews *et al*, 1990a), or near to the tapetal/non-tapetal junction (Rebhun, 1983). They develop outside the plane of the optic fissure and may involve neurosensory retina, RPE and choroid, although usually only RPE involvement is demonstrable on ophthalmoscopy (Matthews *et al*, 1990a). Rubin

(1974) and Rebhun (1983) consider them essentially to be defects in choroidal development, sometimes accompanied by retinal defects. All authors agree that they do not affect vision significantly. Considerable variation in appearance occurs with the most common form being single, or occasionally multiple, sharply demarcated, circular or ovoid, zones of depigmentation overlying normal choroid and, in the peripapillary area, traversed by normal blood vessels (Szutter, 1962; Rubin, 1974; Rebhun, 1983; Matthews *et al*, 1990a). They usually appear as blue or blue-grey lesions, without evidence of inflammation or hyperpigmentation (Rebhun, 1983), and are not progressive (Rubin, 1974). Matthews *et al* (1990a) did state that some may be surrounded by a narrow zone of intense pigmentation and can border the optic disc. It was further suggested that within the RPE coloboma, normal photoreceptor function will be compromised, resulting in minor and insignificant visual field defects, similar in effect to that expected if the neurosensory retina itself were colobomatous.

Other authors (Gelatt and Finocchio, 1970; Koch *et al*, 1978; Riis, 1981; Gelatt, 1982), have described them as being white focal spots, representing pigment loss, without inflammatory changes on histology (Riis, 1981). Koch *et al* (1978) suggested that the term "pigment dystrophy" rather than "atypical coloboma" might be more sensible. The relationship of atypical colobomata to tapetal islands in the non-tapetal fundus (Latimer *et al*, 1983; Blogg, 1985), is difficult to understand, and this author considers that they are the same entity with different degrees of loss of RPE and choroidal tissue. Andrasic *et al* (1963) felt the same way, and termed them all *albinismus fundi partialis*.

Equine Night Blindness (Congenital Stationary Night Blindness).

This is a congential, non-progressive disease which produces visual disturbance in conditions of reduced light or at night (Witzel, Joyce and Smith, 1977; Witzel, Riis, Rebhun and Hillman, 1977; Rubin, Loew, Riis and Laratta, 1984). There is a breed predisposition in the Appaloosa, which is presumed to be hereditary based upon sibling studies (Witzel, Riis, Rebhun and Hillman, 1977). The mode of transmission has not been defined, but is thought to be recessive, or sex-linked recessive, with the defect on the X chromosome (Latimer and Wyman, 1985).

A wide variation occurs in the degree of abnormality, with some horses appearing normal during daylight, but handicapped at night. Others are impaired even in bright illumination. Foals may cock or raise their heads in a stargazing manner, and seek light. Some may exhibit bilateral dorsomedial strabismus.

There are no detectable ophthalmoscopic abnormalities and diagnosis is based on history, behaviour, and electroretinography. Affected individuals have a normal light-adapted ERG, but the dark-adapted ERG lacks a scotopic b-wave, although it has a negative a-wave that increases during dark adaptation (negative ERG) (Witzel, Joyce and Smith 1977; Rubin *et al*, 1984). Histological and electron microscopic examinations of the retina were found to be normal (Witzel, Smith, Wilson and Aquirre, 1978; Rubin *et al*, 1984), and the problem is thought to result from a defect in neural transmission from photoreceptor cell to the bipolar and Müller cells (Lavach, 1990).

Optic Nerve Hypoplasia.

This is an uncommon problem in the horse (Gelatt *et al*, 1969; Gelatt, 1971; Gelatt, 1982; Kern, 1983; Whitley, 1990). Foals bilaterally affected are usually blind and may have a searching nystagmus. Unilateral hypoplasia may not be noticed until weaning or after training begins. Partial vision, or light perception, may be present in affected eyes depending on the degree of hypoplasia (Lavach, 1990). Optic nerve hypoplasia may be associated with other ocular abnormalities such as microphthalmia, retinal detachment, cataract formation, and retinal dysplasia (Whitley, 1990). It is diagnosed ophthalmoscopically. The disc may be smaller than normal (Lavach, 1990), although Rubin (1974) believed that the disc size was relatively normal, and preferred the term congenital optic atrophy. The disc is pale and chalky, with scant or no retinal vessels. The aetiology is unclear, but may be due to an intrauterine inflammatory process (Rubins, 1974). It is probably not hereditary. In some cases it may be clinically indistinguishable from optic nerve atrophy, although histologically the difference is obvious (Munroe and Barnett, 1984).

Optic Nerve Atrophy.

This occurs when the optic nerve itself is injured, or when ganglion cells undergo death subsequent to their initial appearance (Wilcock, 1983). It may be due to a congenital inflammatory process, and has been seen in the foal in association with hydrocephalus (Kern, 1983). In other species it has been caused by viral diseases or hypovitaminosis A (Wilcock, 1983). Traumatic optic nerve atrophy can also occur as an acquired lesion in foals due to blunt trauma, especially when rearing up, falling over backwards and striking the poll (figure 200). In these cases there is a sudden onset of unilateral/bilateral blindness, dilated fixed pupils, negative menace reflex, and progressive pallor of the disc with reduction in retinal vessel number and calibre within 3-6 weeks (Whitley, 1990). Diagnosis is often retrospective and treatment may be ineffective.

Congenital Retinal Detachment.

These are usually bilateral, complete, and cause blindness in foals of any breed, but more commonly in the Thoroughbred and Standardbred (Whitley, 1990). Retinal detachment can occur as an isolated lesion, or in association with retinal dysplasia, cataracts, lens luxation, microphthalmia, and corneal dystrophy (Rebhun, 1983). The detached retina is often dysplastic histologically, and when associated with other ocular abnormalities, probably represents congenital non-attachment of the sensory retina to the retinal pigment epithelium, caused by incomplete invagination of the optic vesicle (Wilcock, 1983).

The retina on ophthalmoscopy appears as a folded grey veil projecting vitread from the optic disc, with a hyper-reflective tapetum (Latimer and Wyman, 1985). The pupils are dilated and fixed in complete detachments (Rebhun, 1983). There is no effective treatment (Rebhun, 1991). Traumatic retinal detachment is very rare in the horse.

Congenital Retinal Dysplasia.

This condition is defined as an abnormal retinal differentiation, with proliferation of neuroblasts or glia within the abnormal neuroectoderm layer (Wilcock, 1983). The lesion is congenital, non-progressive, and visual dysfunction depends upon the severity and extent of the maldevelopment, as well as the presence of other ocular abnormalities (Latimer and Wyman, 1985). Ophthalmoscopically, the fundus may have bizarre focal or diffuse alterations in fundic pigmentation, tapetal reflectivity and colour, and vascularity (Whitley, 1990). Definitive diagnosis is based upon histological identification of the retinal rosette (Wilcock, 1983).

There have been occasional reports of retinal dysplasia in the horse (Rubin, 1974). In a Morgan foal it was associated with retinal detachment, cataracts and microphakia and, in a Thoroughbred foal born blind, associated with only retinal detachment. Four cases were seen by Roberts (1992b), all displaying severe bilateral involvement and poor or no vision. Three of the four cases had other congenital ocular abnormalities. The aetiology is unknown, but 3 pathogenic mechanisms have been proposed (Wilcock, 1983). In some species of animals it is known to be hereditary or virus-induced.

Retinal Cysts.

Peripheral cysts have been observed in mature horses with no other abnormalities, or in conjunction with multiple intraocular congenital abnormalities in foals (Rubin, 1974; Riis, 1981). They involve the inner nuclear and plexiform layers of the retina and may reach considerable sizes. They may be observed bulging into the vitreous. As a sole defect, they probably have little affect on vision, and can spontaneously collapse.

Congenital Retinal Haemorrhage.

This is to be considered in detail in Chapter 16.

Congenital Chorioretinitis.

Infections occurring in the dam may cause disease in the foetal eye (Lavach, 1990), and a case was recorded in a foal from a mare infected prepartum by a respiratory infection (Rubin, 1974). The congenital infection leads to pigmentary changes throughout the fundus (Riis, 1981). Single, or multiple, small foci of depigmentation occur in the non-tapetal fundus and may affect vision if extensive.

15.13 Acquired Abnormalities of the Fundus Affecting the Neonatal Foal.

Acquired disease of the fundus of the foal is uncommon, and is often associated with injury or inflammation elsewhere in the eye.

Optic Neuritis.

This is rare in the young foal, but can be associated with neonatal septicaemia, chorioretinitis, and iridocyclitis (Lavach, 1990; Whitley, 1990). The neuritis can be uni- or bilateral. Blindness can occur in the early active stages, with the pupil dilated and fixed as long as the anterior segment is not involved. Ophthalmoscopic findings include: vitreous turbidity, especially around the disc; swollen hyperaemic optic disc; small haemorrhages on, or near, the disc; peripapillary retinal oedema; and subretinal bullae. The emphasis on treatment is to control the inflammatory process, and to treat anyother systemic or ocular problems. The prognosis is guarded to poor, since partial or complete optic nerve atrophy is a common sequelae.

Retinitis and Chorioretinits.

Because of the vascular supply of the fundus, it is unusual to see these two entities individually in the horse (Rebhun, 1983). Additionally, the shielding affect of the retina from choroidal inflammation by the tapetum, means that the majority of chorioretinal lesions appear in the non-tapetal fundus. Chorioretinitis can occur as a single entity, but usually accompanies iridocyclitis and optic neuritis. Fundic lesions may vary from mild discrete foci to diffuse iridocyclitis and chorioretinitis, and have been reported in foals with septicaemias (Rubin, 1974; Lavach, 1990). Small areas of active chorioretinits appear as grey or greyish-white circular lesions in the non-tapetal fundus (Rebhun, 1983), and have been reported in foals with upper respiratory tract infections. In foals with large numbers of focal lesions, vision may be impaired. These foals usually recover vision as the lesions heal over in one to two weeks. "Bullet hole" scars, or focal choroidal degeneration (Matthews *et al*, 1990), remain in the non-tapetal area. Larger areas of chorioretinitis appear as comma or bar-shaped, or vermiform zones within the non-tapetal fundus and, in severe cases, the tapetal area. In active inflammation, these lesions are dull grey and retinal elevation may occur. As the non-tapetal lesions become inactive, depigmentation occurs and the central region usually becomes hyperpigmented. Tapetal lesions appear hyper-reflective with pigmentation as they become quiescent. Vision is usually poor or absent with, commonly, optic nerve atrophy (Rebhun, 1991).

15.2 RESULTS AND STATISTICS.

15.21 Normal Appearance.

To facilitate the examination and recording of the appearance of the fundus in the foals in this survey, it was divided up into separate anatomical entities.

a) Optic Disc.

Colour.

The colour of the optic disc was recorded in 5 categories and the results are shown in Table 15.1

			Figures
Pale Pink	42	25%	150, 161
Pink	100	59%	162, 151
Red-Pink	23	14%	163, 164
Red	0		
Orange	2		
Unrecordable	2		
Total	169		

5 foals had asymmetrical optic disc colours as detailed in Table 15.2

23	L	Pink	R	Red-Pink
27	L	Red-Pink	R	Pink
106	L	Pink	R	Red-Pink
115	L	Red-Pink	R	Pale Pink
144	L	Red-Pink (figure 165)	R	Pink (figure 166)

Foal 23 had a mild papilloedema in the disc of the right eye. Foal 115 had a difference of 2 categories between the colour of the optic discs, and a haemorrhage in the centre of the optic disc of the left eye (figure 167). Statistically, there was a high correlation between the bilateral optic disc colouration.

The optic disc colour had no statistical relationship with foal sex, behaviour or colour. Overall, there was no correlation with foal size, but a trend towards increased numbers of pink and red-pink colour was seen in <45kg foals, and pink optic discs in the other foal sizes. Optic disc colour was not affected by: foaling category; examination period; presence/absence of vision; ocular reflexes; scleral haemorrhages; pupillary size and shape, including anisocoria; hyaloid artery presence, colour and character; retinal vessel pattern; retinal colour, tapetal and non-tapetal; or border category. It was statistically related to optic disc papilloedema and difficulty in focusing on the disc. In both these groups the number of red-pink discs was increased, a trend which was also noted in foals with retinal haemorrhages (disc and retina).

In general a relationship between optic disc shape and character, and disc colour, could not be established. However, where the homogenous character was noted, there was an increased incidence of red-pink disc colour.

Shape and Character.

The appearance of the optic disc was recorded in 10 shape and 10 character categories (Tables 15.3 and 15.4). In all, 46 combinations of shape and character of the optic disc were used to define each one (see Table 15.5). 5 foals were not bilaterally symmetrical in their optic disc shape and character (see Table 15.6). 2 foals (73, 119) were not recorded because of obstruction to examination by anterior segment disease.

Table 15.3

Shape.			**Figures**
Normal	128	68%	165, 137, 159
Abnormal	1		
Round	8	5%	168
Large	11	6.5%	168
Small	1		157
Flattened Oval	4		169
Distortion Nasal Side	1		170
Triangular	1		160
Ventral Notch	3		171
Dorsal Bulge	20	12%	155, 164

Table 15.4

Character.			**Figures**
Abnormal	2		159, 172
Homogenous	45	27%	164, 160
Light Centre & Border	93	55%	150
Light Centre	16		
Light Border	11		
Mid-ventral White Rim	43	25%	173, 150

Table 15.4

Character.			Figures
Increased Myelination	28	16.5%	
Ragged Edge	11		163, 160
Indistinct Edge	1		
Increased/ Decreased Pigment	1		

Table 15.5

Optic Disc Shape and Character.

N/H	30
N/LCB	44
N/LCB+MVWR	13
N/LCB+IM	12
N/LCB+IM+MVWR	2
N/LCB+RE	1
N/LB	4
N/LB+MVWR	7
N/LC	4
N/IM	1
N/LC+MVWR	2
N/LC+IE	1
N/H+LC	1
N/H+MVWR	3

N/H+IM	1
N/H+RE+DP(dorsal)	1
N/H+MVWR+IM	1
DB/LCB+MVWR+RE	5
DB/MVWR	1
DB/MVWR+IM+LC	3
DB/LCB+IM	3
DB/LCB	2
DB/LC	1
DB+VN/RE+LC	1
DB+IM	1
DB/H+MVWR	1
DB/LCB+MVWR	1
DB/H+RE	1
R+L/H	2
R/LC+IM	1
R/LCB+IM	1
R+S/H	1
R+L/LC+MVWR	1
R+L/LCB+MVWR	1
R+L/H+RE	1
L/H+MVWR	1

L+FO/LCB	3
L+VN/LCB	1
L/LCB+RE+MVWR	1
FO/IM+LCB	1
T/H	1
A/LCB+IM	1
DN/LCB	1
VN/LC	1
Unknown	2

Key

Shape.		**Character.**	
Normal	N	Homogenous	H
Dorsal Bulge	DB	Light Centre & Border	LCB
Ventral Notch	VN	Mid-ventral White Rim	MVWR
Round	R	Increased Myelination	IM
Large	L	Ragged Edge	RE
Small	S	Light Border	LB
Flattened Oval	FO	Light Centre	LC
Triangular	T	Indistinct Edge	IE
Abnormal	A	Decreased Pigment	DP
Distortion Nasal	DN		

Table 15.6

Asymmetry.

23	L	Pink	No Papilloedema	Normal Shape, LCB
	R	Red-Pink	Slight Papilloedema	Normal Shape, sl. H
80	L	Pink	Sl. V. Papilloedema	Normal, LC
	R	Red-Pink	No Papilloedema	Normal, LC
91	L	Red-Pink		Normal,
				Homogenous,
	R	Red-Pink	Dorsal & Ventral IM	MVWR.
115	L	Red-Pink	Central Disc Haemorrhage	Normal,
				Light Centre
	R	Pale Pink	No Haemorrhage	and Border*
116	L	Pale Pink	No Haemorrhage	Normal,
				Light Centre
	R	Pale Pink	Central Disc Haemorrhage	and Border.

* see (figures 167 & 174)

The most common term to describe the optic disc was normal, which is defined as an oval of regular symmetry. 76% of foals fitted into this category, whilst a flattening of the oval was seen in 4 foals. A more rounded shape, although not circular, was seen in 8 foals (5%). The disc appeared larger than normal in 11 foals (6.5%), but smaller only in one. 3 foals had ventral notching of the disc, 2 of which also had a slight dorsal indentation. 1 other foal had a dorsal indentation and flattening. 20 foals (12%) had a dorsal bulging, or extension of the disc, which required careful differentiation from those with increased myelination (see character section). 1 foal had a triangular shape and 1 other had a disc not symmetrical but distorted on the nasal side. 4 foals in the normal shape group had slight nasal blunting which was not considered significant enough to place them outside this catergory.

Many foals had several terms to describe their disc character, often up to four. 93 foals (55%) were described as having a light centre and border, with 16 (9.5%) the light centre only, and 11 (6.5%) the light border only. In contrast, 45 foals (27%) were homogenous and even in appearance across the disc. 2 foals had an optic disc haemorrhage, and were classified as abnormal (see Chapter 16). 43 foals (25%) had a mid-ventral white rim and 28 (16.5%) the condition known as increased myelination. In contrast to most foals which have a smooth outline to their discs, 11 foals had a ragged edge and 1 was indistinct, possibly associated with papilloedema.

The variation in description of the optic disc was large and many categories contained only one or two examples. The more common descriptions are included in Table 15.7.

Normal, light centre and border	44	(26%)
Normal, homogenous	30	(17.75%)
Normal, light centre and border, MVWR	13	(7.5%)
Normal, light centre and border, increased myelination	12	(7%)
Normal, light border, MVWR	7	
Dorsal bulge, ragged edge, light centre and border, MVWR	5	
Normal, light border	4	
Normal, light centre	4	

Location.

All the optic discs were situated in the non-tapetal fundus, just below the junction or border between the non-tapetal and tapetal parts of the fundus. One foal (142) had an optic disc that was slightly closer to the tapetal/non-tapetal fundus border than usual. This was associated with a larger than normal, round disc, but no extension of the border towards the disc, or dorsal to the disc depigmentation. No other ophthalmic anomalies were detected in this case.

Appearance.

Retinal Haemorrhages.

2 foals had retinal haemorrhages on the disc (117, 118) (figure 167). Both were unilateral, one left, one right. Both were red, large, splash-type, fresh haemorrhages centred over the middle of the disc. In one foal there was a difference between the eyes in the optic disc colour (see earlier). Neither foal had papilloedema or retinal vessel abnormalities. Both foals were clinically normal.

Papilloedema/Unfocusable Disc.

The following foals had obvious papilloedema or a disc, or part of it, that was not possible to focus sharply onto.

16 Normal foal and foaling. Large, homogenous, red-pink disc with haemorrhage in right eye around a dorsal retinal vessel adjacent to the disc. Difficulty in focusing onto both discs.

23 Normal foal and foaling. Normal shaped disc with light centre and border. Left eye pink, right eye red-pink with slight difficulty in focusing.

25 Normal foal and foaling. Normal shaped, red-pink disc with light centre and increased myelination. Difficulty in focusing nasal inferior border of both discs.

68 Weak foal with difficulty sucking. Mare with history of producing weak foals and abnormal placentae. Normal shaped, pale pink discs with light centre and border, and mid-ventral white rim. Difficulty focusing both disc edges.

69 Dysmature foal with CNS signs, due to placentitis. Not blind but PLR negative until day 5. Bilateral secondary entropion. Normal shaped, red-pink, homogenous disc with more visible retinal vessels than usual and papilloedema.

77 Normal foal born to category 3 foaling. Normal shaped, pink, homogenous disc with slight difficulty in focusing and tortuous, more prominent retinal vessels in the right eye.

80 Normal, overdue foal born to category 3 foaling requiring extensive assistance. Normal shaped, pink, light centre discs with no abnormality in right eye but slight difficulty in focusing on inferior temporal and nasal borders in left eye.

89 Very large, normal foal with category 3 foaling. Normal shaped, red-pink, light centre and border discs with slight papilloedema.

97 Large, normal foal with category 3 foaling and prolonged second stage. Normal shaped, red-pink, discs with obvious papilloedema.

99 Normal, large foal with category 4 foaling. Normal shaped, pink, homogenous disc with mild papilloedema and large numbers of retinal haemorrhages in right eye and bilateral scleral haemorrhages.

102 Normal foal with category 4 foaling. Normal shaped, red-pink, homogenous discs with slight papilloedema bilaterally and retinal haemorrhages in the right eye. Less distinct retinal vessels.

107 Normal foal born to normal foaling. Normal shaped, red-pink homogenous discs with slight papilloedema and bilateral retinal haemorrhages.

111 NMS foal with severe CNS signs, blindness and anisocoria. Normal shaped disc, reddish-pink, slightly light centred disc, with severe papilloedema in both eyes and increased tortuosity of retinal vessels. Bilateral retinal haemorrhages. As the foal improved over 4 days, the degree of papilloedema decreased with the disc becoming paler and the edges more obvious. Retinal vessel tortuosity also decreased.

114 Normal foal to unattended foaling. Normal shaped, pink, light centre and border, disc with difficulty in focusing on disc, especially right side, and more obvious retinal vessel pattern. Bilateral retinal haemorrhages.

Table 15.8 summarises the clinical information of the affected foals in the papilloedema/unfocusable group.

Papilloedema			**Unfocusable only**			**Foal Behaviour**		
	7			7				
BIL	**L**	**R**	**BIL**	**L**	**R**	**N**	**ABN**	
6	0	1	5	1	1	11	3	2 CNS 1other

Foaling Category	
1	6
2	0
3	4
4	4
5	0

Disc Shape	
N	13
ABN	1

Disc Colour	
PP	1
P	4
RP	9
R	0

Disc Character	
Homogenous	6
Other	8

Ret. Vessel Pattern	
N	8
ABN	6

Retinal Haemorrhages
5
Scleral Haemorrhages
1

Table 15.8

Foal Sex		**Foal Size**		**Pregnancy History**	
M	5	**<45kg**	**45-50kg**	**N**	**9**
F	9	0	9	**ABN**	**5**
		51-55kg	**>55kg**	3 overdue	
		2	3	1 placentitis	
				1 abnormal uterus	

Parity	**Exam. Period (hrs.)**				**Vision**	
All multiparous	**24**	10	**48**	4	**Y**	13
	72	0	**96**	0	**N**	1

Menace	**Pupillary Light Reflex**		**PLR Rapidity**	
All negative	**+ve**	4	**O**	1
Anisocoria	**abn.**	9	**Slow**	9
1	**-ve**	1	**Sluggish**	2
			Rapid	2

Key

BIL = Bilateral L = Left R = Right N = Normal

ABN = Abnormal PP = Pale Pink P = Pink RP = Red Pink

R = Red M = Male F = Female Y = Yes N = No

7 Foals had definite papilloedema, and 7 foals had discs, or part of discs, that were unfocusable. The majority of foals (6 of 7 and 5 of 7) were affected bilaterally. The statistical relationship of papilloedema and unfocusable discs to various parameters was undertaken but, because of the small numbers, care in interpretation is needed. Female and heavier (>/= 50kg) foals were over represented. 3 foals had abnormal behaviour, all in group 2 behavioural abnormalities, with 2 of these 3 having severe CNS signs and 1 of them being

blind. All 3 abnormal foals had papilloedema. There appears to be a relationship between foaling category and papilloedema/unfocusable discs with 3 and 4 being overrepresented. All of the foals in these groups were born to multiparous mares. There was, in general, no statistically significant relationship between abnormal pregnancy and the incidence of papilloedema/unfocusable discs, but greater than 20 day gestational length occurred in 3 mares, and both other abnormalities lead to abnormal foals with papilloedema. Examination period, presence of vision and PLR reflexes were not related to this group, but menace reflex was negative in all foals.

The presence of anisocoria was recorded in 1 foal which also exhibited blindness, negative PLR reflexes, abnormal CNS behaviour, retinal haemorrhages, and the most severe papilloedema. All these signs suggest significant CNS damage. Overall, anisocoria and papilloedema were not connected. Papilloedema/unfocusable discs were related to optic disc colour and character, with red-pink colour and homogenous character being overrepresented. Optic disc shape was not related, but retinal vessel pattern abnormalities were. The incidence of retinal and scleral hamorrhages was significantly higher in this group of foals.

b) Retinal Vessel Pattern.

The vessel pattern was recorded in Table 15.9.

			Figure
Normal	133		147, 164, 165
Abnormal	34		
Unrecordable	2		
Increased tortuosity of vessels			
Intra-disc	3		152
Extra-disc	11		175
Increased size of vessels	8	> diameter	173
	2	> length	
Decreased size of vessels	0		
Increased numbers of vessels	0		
Decreased numbers of vessels	1		176
Haemorrhage around vessels	1		177
Less distinct vessel pattern	2		
More distinct vessel pattern	15		157, 178, 147

20% of foals (34) were recorded as having a retinal vessel pattern outside the normal range. Of these by far the most numerous categories were increased visualisation of the vessel pattern (15), and increased tortuosity of vessels (14). 78% of the increased tortuosity group occurred outside the disc margins, but in 3 foals there were tortuous vessels present on the disc. 4 of the extra-disc and 5 of the increased vessel size groups were also present in the more distinct vessel pattern group. 10 foals had increased size of vessels, the majority (8) being of increased diameter and only 2, of extra length. There were none with decreased vessel size, but one foal did have decreased numbers of vessels. This foal had a fundic lesion. One foal had haemorrhage around a vessel in the dorsal papillary area, associated with a partially unfocusable disc, and 2 foals had a less obvious vessel pattern. One was not associated with any vessel or fundic abnormality, but the other did have papilloedema.

There was no significant relationship between retinal vessel pattern and breed, foal sex, size, colour or behaviour, examination period, foal vision or menace/PLR reflex, scleral haemorrhages, anisocoria, presence of hyaloid apparatus or optic disc shape. Overall there is no significant relationship between retinal vessel pattern and foaling category, although foaling category 3 is over represented. There are significantly higher numbers of pale pink and red-pink optic disc colourations. Bilateral retinal vessel pattern changes occurred in 29 foals (85%), with 2 left only, and 3 right only. Retinal haemorrhages and optic disc papilloedema/unfocusable were significantly overrepresented in this group. Overall, retinal vessel pattern was not related to tapetal fundus colour, but category 4 was lower and category 5 was greater than expected. There was no relationship with the presence of choroidal vessels. There was a strong association with the presence of atypical colobomas in the non-tapetal fundus, and less so with ragged border and dorsal-to-disc depigmentation in the non-tapetal fundus.

c) Tapetal Fundus.

Colour.

The colour of the tapetal fundus as recorded is shown in Table 15.10.

1. Yellow	**2.** Yellow-Orange with Green outer border	**3.** Nasal Yellow/Temporal Green	**4.** Green with Yellow periphery
8	22 (1 foal R eye 1)	0	34
5. Yellow-Green	**6.** Green	**7.** Blue	**8.** Mottling dorsally
88	7	0	166
9.	**Combination 6/7.**	**Combination 7/5.**	**Combination 5/7.**
Albinism	Blue with Green border	Blue with Yellow-Green periphery	Yellow-Green with Blue periphery
0	5	1	1
Combination 4/7.	**Unrecordable**	**Not Mottled**	**Decreased Mottling**
Green-Yellow with Blue border	2	1 Yellow 1.	1 y 4 3 y/g
1			

Table 15.10

	Grey-Brown Mottling		Dark Brown Mottling
	1 g	**6.**	
	4 y/g	**5.**	158
8	1 g/y	**4.**	
	1 y	**1.**	
	1	**2.**	

Difference Between Sides in Tapetal Fundus.

1	R eye yellow decreased mottling
	L eye yellow-green normal mottling

The most common combinations for describing the tapetal fundus are shown in Table 15.11.

Yellow-Green + Dorsal Mottling	88 (52%)
Green with Yellow periphery + Dorsal Mottling	34 (20%)
Yellow-Orange with Green periphery + Dorsal Mottling	22 (13%)
Yellow + Dorsal Mottling	7 (4%)
Green + Dorsal Mottling	7 (4%)
Blue with Green Periphery + Dorsal Mottling	5 (3%)

88 foals in this survey had yellow-green tapetal fundi (figures 154, 160 & 162), 34 green with yellow periphery (figures 137, 138 & 182), and 22 yellow-orange with green outer edge (figure 146). 8 had yellow (figures 179 & 181) and 7 green (figure 167) tapetal fundi, with no blue colouration or albinism. A few foals had mixtures of colours, usually involving various combinations of blue pigmentation (figures 153, 176 & 177). 99.5% of foals had mottling of the tapetal fundus colouration dorsally (figures 146, 148, 179, 180 & 181). Only 1 foal did not have this mottling and in 4 it was markedly reduced. In the majority of foals (95%), the mottling was dark brown, but in 8 foals it was of a grey-brown colour (figure 179).

The most common combinations of categories to describe the neonatal foal's tapetal fundus were used in a statistical analysis to determine their relationship to other parameters in the survey. The tapetal fundus colour was not statistically related to: foal sex or colour; examination period; vision and ocular reflexes; presence of hyaloid artery; optic disc colour; border category; retinal haemorrhages. It was strongly correlated with foal behaviour, although no obvious pattern was evident. Nictitans colour and tapetal fundus were related, with whole-coloured pink third eyelids being more common in green with yellow periphery (category 4) colouration, and pink, black edge in tapetal fundi with increased blue or yellow pigmentation (7, 2, 1). Scleral shelves/pectinate lines were more obvious in foals with green-yellow periphery (4) and less so in categories 2 and 7. Overall, there was no relationship between iris colour and tapetal fundus colour, but this was affected by the large number of cells in the Chisquare calculation with expected values less than 5. If these are removed, dark brown and grey-brown iris colour are related to yellow-green and green with yellow periphery tapetal fundus colouration. There appears to be a significant relationship between tapetal and non-tapetal fundus colouration. Yellow-orange tapetal fundus (category 2) is correlated with light brown-grey non-tapetal fundus; yellow-green tapetal with dark brown non-tapetal fundus; and green-yellow with dark brown and dorsal-to-disc depigmentation. The presence of choroidal vessels, especially of a red colour, were strongly related, statistically, with tapetal colouration, especially green-yellow and yellow. Their presence was much less common in yellow-orange and yellow-green tapetal fundi.

Stars of Winslow.

All 167 foals with fundi that were recordable, had Stars of Winslow present. The colour of these was related to the tapetal fundus colouration (figures 99, 138, 153, 154 & 160).

Choroidal Vessels

Table 15.12 shows the data collected in this survey on choroidal vessels.

Table 15.12

No.	POS 1	POS 2	COLOUR		TYPE	
			Red	Purple	End-on.	Long.
42	42	0	37	5	4	6
					10 recorded	

BIL	Left	Right
38	2	2

42 foals had choroidal vessels visible in the fundus and all were in the area immediately dorsal to the disc, running from the disc through the border up into the tapetal fundus (figures 137, 159, 160 & 165). 37 foals had vessels that appeared red or pink in colour (figures 159 & 165), 5 were purplish or mauve (figure 164). Of the 10 foals where the type of vessels seen was recorded, 2 were end-on (figure 155), 4 longitudinal (figures 138 & 159) and 2 both types present together. Choroidal vessels were bilaterally present in 38 foals and 2 foals had them just present in the left or right eyes.

Statistical analysis showed there to be no significant correlation between the incidence of choroidal vessels and foal breed, sex, behaviour, examination period, vision and ophthalmic reflexes. Overall, there was no relationship with foal colour (increased numbers of bay and bay-brown foals), nictitans colour (pink, black edge over represented), or iris colour (grey-brown higher numbers). Optic disc colour and border type were not related, although extension of the border towards the disc was strongly correlated, albeit involving only small numbers of foals. Tapetal and non-tapetal fundus colour were statistically related to the incidence of choroidal vessels. Green-yellow, yellow, and possibly green-blue tapetal colouration showed an increased incidence. Dorsal disc pigmentation was seen in 40 of the 42 foals with choroidal vessels and is the single most significant factor in the occurrence of choroidal vessels. Light brown-grey non-tapetal fundus and the presence of atypical colobomata may have a less significant effect. Retinal and scleral haemorrhage incidence was not affected by the presence of choroidal vessels.

d) Non-Tapetal Fundus.

Border.

The results of the type of border between the tapetal and non-tapetal fundus are shown in Table 15.13.

			Figures
Straight	146	(87%)	138, 154, 158, 165, 177
Ragged	21	(12.5%)	183, 184, 197
Atypical Coloboma near border	16	(9.5%)	185
Extension towards Disc	0		
Border less obvious	3		157
Unrecordable	2		

The most common combinations used to describe the border are shown in Table 15.14.

Straight only	133	(79%)
Ragged only	15	(9%)
Straight and Atypical Coloboma (near border)	10	(6%)
Ragged and Atypical Coloboma (near border)	6	(3.5%)
Straight and not distinct especially over disc	3	
Unrecordable	2	

The border was present between the tapetal and non-tapetal fundus in all recordable foals, but was indistinct, especially over the optic disc, in 3 foals. 79% of foals had a straight, distinct border with a further 10 foals also having atypical colobomata close to the straight border. 21 foals had a ragged, uneven border, of which 6 foals also had atypical colobomata close to the border.

The border pattern was not significantly affected by: foal colour, sex or behaviour; examination period; vision and ophthalmic reflexes; scleral or retinal haemorrhages; optic disc and tapetal colouration; or choroidal vessel incidence. Nictitans and iris colour are both, overall, significantly related to border type, but there is no obvious pattern to this relationship. It is likely that the high number of calculation cells with expected values less than 2 adversely affected the Chisquare determination. The border type and non-tapetal fundus colouration are statistically related. A straight, normal border is strongly correlated with a dark brown non-tapetal fundus, and a ragged border with light brown-grey non-tapetal fundus with atypical colobomata.

Colour.

The colour of the non-tapetal fundus in the foals in this survey is recorded in Table 15.15.

			Figures
Dark Brown	129	(77%)	156, 159, 186
Grey-Brown	34	(20%)	132, 165
Black	3		158
Grey-Green	1		
Unrecordable	2		

77% (129) of the foals had a dark brown colour to the non-tapetal fundus, whist 34 foals were a lighter grey-brown. Only 4 foals had other colours in this survey: 3 black and 1 an unusual grey-green colouration.

Appearance.

The appearance of the non-tapetal fundus is recorded in Table 15.16.

			Figures
Normal, Homogenous	94	(56%)	182, 186
Atypical Coloboma (whole area)	18	(11%)	141, 172, 185, 187
Dorsal-to-Disc Depigmentation	66	(39%)	147, 160, 164, 165
Light Grey Streaks	0		
Others	1		176, 188
Unrecordable	2		

The majority of foals had a dark brown non-tapetal fundus. 20% of foals did, however, have a grey-brown colouration. 56% of foals had a normal homogenous appearance to the non-tapetal fundus, but 39% (66 foals) had dorsal-to-disc depigmentation. This varied in extent from a small area immediately dorsal to the disc and ventral to the border, to a large area running from the equator of the disc dorsally to include the border and part of the tapetal fundus. The degree of depigmentation varied and was often associated with choroidal vessel appearance in those where it was most obvious. 1 foal had depigmentation in a circle around the entire disc of approximately 1 disc's diameter radius. This was associated with loss of border clarity in this area (see border section). Dorsal-to-disc depigmentation appeared more commonly in those foals with a grey-brown non-tapetal fundus, whereas homogenous appearance was relatively more common with dark brown colouration. 18 foals had atypical colobomata in the non-tapetal fundus, 12 of which also had dorsal-disc-depigmentation. Atypical colobomata were slightly more common with dark brown pigmentation. No foals were recorded as having grey streaks in the non-tapetal fundus.

Overall Description.

The description of the non-tapetal fundus using a combination of colour and appearance is recorded in Table 15.17

Dark Brown and Homogenous	78	(46%)
Dark Brown and Dorsal-to-Disc Depigmentation	35	(21%)
Grey-Brown and Dorsal-to-Disc Depigmentation	18	(11%)
Grey-Brown and Homogenous	14	(8%)
Dark Brown, Atypical Coloboma and Dorsal-to-Disc Depigmentation	10	(6%)
Dark Brown and Atypical Coloboma	5	(3%)
Black and Homogenous	2	
Black and Dorsal-to-Disc Depigmentation	1	
Grey-Green and Atypical Coloboma	1	
Grey-Brown, Atypical Coloboma and Dorsal-to-Disc Depigmentation	2	

Statistically the colour and appearance of the non-tapetal fundus were not related to: foal sex and behaviour; vision and ophthalmic reflexes; examination period; scleral and retinal haemorrhages; optic disc colouration. They were strongly correlated with foal colour, with dark brown/homogenous and dark brown/dorsal depigmentation seen more commonly in bay foals. Chestnut and grey foals tended to have brown-grey/dorsal depigmentation non-tapetal fundi. The relationship between the non-tapetal fundus and nictitans colour was less clear, but pink/black edge was more common in dark brown/homogenous, and whole coloured pink nictitans was overrepresented in grey-brown/dorsal-to-disc depigmentation. Iris colour and non-tapetal fundus colour and appearance were correlated; with dark brown iris colour related to dark brown/homogenous; and grey-brown iris colour with grey-brown/homogenous, dark brown/dorsal-to-disc depigmentation, and grey-brown/dorsal-to-disc depigmentation. As would be expected, these last two categories of non-tapetal fundus appearance were statistically related to the incidence of choroidal vessels.

Non-tapetal and tapetal fundic colouration and appearance were statistically related. Dark brown/homogenous non-tapetum was correlated with yellow-green/dorsal mottling tapetal fundus; dark brown/dorsal-to-disc depigmentation with green-yellow/dorsal mottling; and yellow-orange/green border/dorsal mottling with grey-brown/homogenous non-tapetal fundus.

15.22 Congenital Abnormalities of the Fundus.

The incidence of congenital abnormalities of the fundus in this survey was high, with 46 foals (27%) having changes. Of these, 27 foals had retinal haemorrhages which will be discussed in detail in Chapter 16, and 18 foals had atypical colobomata. Only 1 foal had changes of the fundus not in these two groups, namely a peripapillary congenital chorioretinitis with associated vitreal opacities and lens cataracts.

Atypical Coloboma.

The incidence and morphology of the atypical colobomata in this survey were recorded in detail and are shown in Table 15.18.

			Figure
Colour	Light Blue	6	185
	Blue	13	
	Temporal	13	185
Position	Unrecorded	1	
	Nasal	7	187
Number	One	12	172, 185

Table 15.18			Figure
	Two	4	
	Three	2	
	> Four	1	187
Shape	Small Linear	1	
	Small Round	11	172, 187
	Medium Ragged	5	185
	Large Ragged	2	
	Yellow	1	
	Yellow-Orange	2	
Tapetal	Green	1	
Fundus	Green-Yellow	7	
Colour	Blue-Green	1	
	Yellow-Green	6	
Unilateral	Left	4	
	Right	8	
Bilateral		6	
Position in Non-Tapetum			
	Border	16	185
	Below Disc	3	187
Equatorial Distribution			
	a	9	185
	b	10	172
	c	0	
	abc	2	
Straight Border		11	
Ragged Border		7	

18 foals (11%) had atypical colobomata somewhere in the non-tapetal fundus. 15 of these occurred only immediately in the border area i.e. between the level of the disc equator and the actual border. 2 foals had colobomata below the level of the disc and 1 foal had colobomata in both border and below disc areas.

Colobomata were significantly more common in ragged borders, green-yellow and blue-green tapetal fundi.

The colour of the colobomata was reported as light or pale blue (5 foals) and blue (12 foals). 1 foal had a left eye coloboma which was pale blue and a right eye coloboma which was blue. The paler colour tended to be seen in foals with increased yellow pigment in their tapetal fundus colouration. The darker blue was more common in the green or greenish-blue tapetal fundi. Overall, there was little correlation between atypical coloboma incidence and non-tapetal fundus colour, but dark brown was slightly overrepresented. There was a significant relationship between the incidence of atypical coloboma and dorsal-to-disc depigmentation.

4 foals had colobomata in their left eye only, 8 in the right eye only, and 6 were bilaterally affected. 11 foals had colobomata on the temporal side of the disc, 5 nasally, 1 nasal in the right eye and temporal in the left eye, and 1 temporal and nasal in the same eye. 1 foal was unrecorded.

11 foals had only one coloboma; 4 foals only 2; 1 foal 3 colobomata; 1 foal multiple colobomata; and 1 foal, 1 in the left eye and 3 in the right. The shape of the colobomata was described as small, round with distinct edges in 9 foals; small and linear in 1 foal; medium sized with ragged, uneven edges in 5 foals; large (disc-sized) and ragged in 1 foal. 1 foal had three small round colobomata in the right eye and 1 large ragged coloboma in the left eye. The colobomata were positioned within 2 disc diameters (a) of the optic disc in 7 foals; within 4 disc diameters (b) in 10 foals, including a right eye (94); and within the length of the visible fundus (abc) in 2 foals (including the left eye of 94).

Statistically, in this survey, there was no correlation between the incidence of any foal, gestational/parturiant, or ophthalmic abnormality and that of atypical colobomata.

Congenital Chorioretinitis.

Foal 152, which has already been discussed in chapters 13 and 14, had a unilateral (right eye), peripapillary chorioretinitis or choroidal/retinal pigment epithelium degeneration (figures 176 & 188). The left eye was normal. The fundic lesions consisted of a discrete area around the whole disc, but mainly medial and lateral to the disc in the non-tapetal fundus, of loss of pigmentation and change in colour of both areas of the fundi. The non-tapetal area took on a bluish colour and the tapetal area was orange. There were within this area points of focal pigmentation, especially around the retinal vessels. The retinal vessels appeared thickened in diameter and decreased in numbers. Within the depigmented area there was evidence of choroidal vasculature. Elsewhere in the non-tapetal fundus, further ventrally to the disc, there were small focal lesions of similar pigment loss and hyperpigmentation.

The foal was normal, with no visual deficits, and the rest of the fundus, including the optic disc, was normal. The lesions appeared non-progressive and non-active, and subsequent examination over a period of weeks revealed no changes in the fundus.

15.23 Acquired Abnormalities of the Fundus.

No acquired abnormalities of the fundus were detected in this survey. It was not possible to examine the fundus of 2 foals with severe anterior segment inflammation, and it is possible, considering the degree of iridocyclitis present, that optic neuritis and/or chorioretinitis might also have been present.

15.3 DISCUSSION.

15.31 Normal Appearance.

The fundus of the foal is generally considered to be similar to the adult (Latimer and Wyman, 1985), but several differences do exist (Munroe and Barnett, 1984), especially in the neonate, and these were highlighted in this survey.

a) Optic Disc.

There was a huge variation in the shape, character, appearance and colour of the optic discs in this survey. Latimer *et al* (1983) also found a considerable variation in a survey of older foals, and Rebhun (1991) in adults. Koch *et al* (1978), however, stated that in their survey of 82, mainly Thoroughbred foals of between 0 and 30 days, all of the optic discs were similar in size and vascularity. One constant in the survey was the location of the optic disc within the non-tapetal fundus, approximately a 1/4 to 1/2 a disc diameter below the border between the two fundic areas. The single foal detected with a disc closer than this was probably related more to disc size than abnormal location in the fundus.

Colour.

The colour of the optic discs in this survey varied on initial examination but was found to be bilaterally symmetrical in all but 5 foals. In 2 of these foals there was an obvious reason for a difference in colour, namely mild papilloedema and retinal haemorrhage on the disc. Both these conditions were found to significantly affect disc colour in this survey, usually leading to a red-pink disc (see later sections and Chapter 16). Foal 106 had retinal haemorrhages in the tapetal fundus, but not the optic disc.

The change in colour of the optic disc as the foal ages was not confirmed in this survey, since there was no overall relationship of this to examination time. A trend was, however, established of increased numbers of pale pink and pink colouration after 48 hours and red-pink in the first 24 hours. Frauenfelder (1983) found very similar relationships with time in his survey. Confirmation of this was seen in those foals where serial examinations were made, for instance in retinal haemorrhages, where a subjective impression was formed of a lightening and less homogenity of disc colour with ageing. This lack of homogenity of colour in much older foals has been described as fasciculated or fibrous in appearance (Gelatt, 1982; Latimer *et al*, 1983), and closely resembles the adult disc. Frauenfelder (1983) found that 11% of the foals he examined within 24 hours of birth had an even red hue to the whole disc, with darker colour appearing to gradually contract towards the edges in the following 24 hours.

60% of foals in this survey had a pink disc on first examination, 25% pale pink, and 14% red-pink. At no stage were red optic discs seen, although 2 foals had orange coloured discs previously recorded by Gelatt (1969) in adults. Frauenfelder (1983) found pink, pale pink and red-pink discs in 50%, 27% and 15% respectively of neonatal Thoroughbred foals examined before 5 days old. This remarkable similarity in results is somewhat tarnished by the additional finding of 14 foals with red discs in this earlier survey. The difference may be a matter of subjective assessment of degree, and certainly some of the red-pink discs in this survey were close to being described as red.

Frauenfelder (1983) stated that the colour of the optic disc may be a useful sign for detection of subclinical levels of birth trauma, which could lead to cerebral oedema. He considered the red optic disc to be a sort of "half-way house" between the normal disc and papilloedema, suggesting that the reddish hue that develops during papilloedema regression further supported this theory. This is probably an oversimplification of the case but, nevertheless, in this survey red-pink disc colour was strongly related to papilloedema/unfocusable discs, or part thereof, and retinal haemorrhages. Further discussion of these findings will be undertaken in the relevant sections and Chapter 16, but these abnormalities may well be an ophthalmic manifestation of CNS changes.

A connection of disc colour with shape in this survey was not established, which confirms previous work (Munroe and Barnett, 1984). The relationship of colour and character was in general not confirmed but, as previously stated, those discs with red-pink colour had a higher incidence of homogenous appearance.

Shape and Character.

The enormous variation in the appearance of the optic disc in this survey is reflected by the large number of combinations of shape and character defined in the results. Previous work in both foals (Latimer *et al*, 1983) and adults (Rebhun, 1991) has noted this extreme variability. Bilateral symmetry was seen in all but 5 foals, 2 of which had asymmetrical optic disc colour. 2 foals had asymmetrical mild papilloedema and a further 2 foals had disc haemorrhages only in one eye. In the foals with papilloedema the discs were described as homogenous in appearance, whereas the disc haemorrhages did not affect the overall character of the disc. In 1 foal there was bilateral variability in the degree of increased myelination around a disc. The findings of asymmetry in disc character were very similar to that seen in optic disc colour, in that both were mainly related to conditions with a possible CNS component.

There appeared, in general, to be less variability in the range of descriptions applied to optic disc shape compared to character. The majority of foals in this survey had an optic disc shape of a regular oval which has previously been described in the literature as the normal shape for foals (Latimer *et al*, 1983; Munroe and Barnett, 1984; Latimer and Wyman, 1985). Lavach (1990) suggested that in foals the disc is more round, and Latimer *et al* (1983) had 5 foals with discs so described. 8 foals were recorded with round discs in this survey. 4 foals had discs that were dorsally and ventrally flattened, which has previously been described by Koch *et al* (1983) in Thoroughbred foals. The considerable number of foals with discs larger than normal (11) has not been recorded before. These foals, and the single foal with the small disc, did not have any significant relationship with any foal or ophthalmic abnormality, and must be considered normal variations. Other variations in shape seen in this survey were dorsal bulges of the disc and single foals with triangular and nasally distorted discs. These variations in shape have been recorded previously in older foals (Latimer *et al* 1983) and are thought to be within normal limits. Ventral notching previously described in adults by Lavach (1990) and Matthews *et al* (1990a) were recorded in 3 foals, and are thought to be related to the embryonic optic fissure.

The variability in the optic disc character meant many foals had combinations of categories to describe them. A large number of foals (55%) had a light centre and border to the disc separated by areas of disc of a varying colour density. Other foals had the light border or centre only. A similar appearance was described, albeit in slightly different terms, by Latimer *et al* (1983) and can be detected in the adult as well (Matthews *et al*, 1990a). The darker border mentioned by Barnett (1975) and noted as concentric pink rings by Latimer *et al* (1983) are thought to be the same as the area of disc seen between the border and centre in this survey. Rubin (1974) suggested that the light border of the disc periphery was due to this area being slightly raised. In contrast to these discs, 27% of foals had discs which were even or homogenous in appearance. This category was more common in younger foals, those with red-pink discs, and in papilloedema and retinal haemorrhages. The homogenity of the optic disc in the young foal and its gradual change to the more adult pattern has been discussed earlier, particularly in relation to red-pink colouration, and may be due to changes in vascularity, optic nerve swelling, and fibrous content in the disc. Retinal vasculature changes and optic nerve swelling are also seen in papilloedema and retinal haemorrhages, and may provide a link between these various parameters.

A large number of foals (25%) had an obvious white rim in the mid-ventral optic disc which has been described previously by Koch *et al* (1978) and Latimer *et al* (1983) in foals. Rubin (1974) considered that the rim represented myelin, or a local variation in vascularity. 28 foals in this survey were described as having variable degrees of increased myelination. Matthews *et al* (1990a) noted this condition in the adult horse and suggested that it was due to retention of retinal nerve fibres' myelin sheaths beyond the lamina cribosa of the optic disc. Rebhun (1991) felt that the condition was more common in older animals. It was stated that these myelin sheaths appeared as grey striae extending for a variable distance from the disc margin, usually on the infralateral and inframedial aspects. Those cases seen in this survey, were usually less than those seen in the adult in both size and prominence, but were similar in positions.

Only one foal was seen with pigment variation in the optic disc, a condition which has been reported by Latimer *et al* (1983) in the foal, and Matthews *et al* (1990a) in the adult. The latter thought that this was due to congenital entrapment oı undifferentiated retinal pigment epithelium cells within the optic stalk during fissure closure.

11 foals had a ragged edge to the disc outline in contrast to the usual smooth form. Lavach (1990), Matthews *et al* (1990a), and Rebhun (1991) all noted that the disc margin in the adult horse could be scalloped or irregular to variable degrees, whilst Barnett (1975) and Lavach (1990) stated that in the foal it was often smooth and clear.

Appearance.

Optic Disc Retinal Haemorrhages.

2 foals with optic disc retinal haemorrhages will be discussed in Chapter 16, but have been recorded only once before by Barnett (1975). Their appearance and resorption process did not appear to differ from retinal haemorrhages

in the tapetal fundus, although their origin must have been from local retinal vessels rather than choroidal vasculature.

Papilloedema.

Papilloedema is a condition where the optic disc becomes oedematous, raised, enlarged and haemorrhagic. The edges of the disc are indistinct (Palmer, 1976). The cause of papilloedema may be related to interference with the venous return from the optic nerve, or it may be an extension of the oedema of white matter in the brain itself (Palmer, Malinowski and Barnett, 1974). It has been recorded in the horse in association with retrobulbar inflammation and haemorrhage, meningitis, internal hydrocephalus, and increased intracranial pressure (Gelatt, 1982). Lavach (1990) stated that papilloedema was often difficult to appreciate in the horse by transillumination or by direct ophthalmoscopy, and he recommended the use of a binocular indirect ophthalmoscope. Gelatt (1982) found that in papilloedema the optic nerve surface was raised 3-10 diopters above the ocular fundus and retinal blood vessels were congested. He also recorded oedema and congestion of vessels on the optic disc and peripapillary fundus. The condition needs careful differentiation from optic neuritis. Frauenfelder (1983) recorded varying degrees of papilloedema in neonatal foals, both normal and abnormal, and considered it to indicate cerebral oedema. He considered detection of papilloedema, and possibly disc colour changes (see earlier), to be a useful diagnostic aid in assessing any foal, especially if it had abnormal Group 2 neonatal behaviour. Multiple retinal haemorrhages and scleral splashing, papilloedema, and variable pupil size have been described in association with Neonatal Maladjustment Syndrome (NMS) (Munroe and Barnett, 1984). These authors further commented that the haemorrhages may be incidental, but that the papilloedema and variable pupil size were not.

7 foals in this survey had definite papilloedema at the time of first examination. This was diagnosed by detecting that no part of the optic disc could be accurately focused, using the Diopter scale, and that the retinal blood vessels could not be seen running across the edge of the disc. In more severe cases there was obvious congestion of the retinal vessels on the disc head and lack of clarity of the peripapillary fundus. In 7 other foals, parts of the optic disc became indistinct and were difficult to bring into focus. The amount of the disc so affected varied between 25-50% and could affect more than one area of the disc. In these cases the retinal vessels were often less obviously affected, although occasionally it

appeared as though they "fell off" the raised area of the disc, leading to a kinking or dipping of the vessels at this point. Frauenfelder (1983) also recorded these variations in degree of difficulty in focusing on the disc, and was happy to classify them all as papilloedema. He recorded an incidence of 12 foals (20 eyes) in 180 neonatal Thoroughbred foals examined within 72 hours of birth. This survey recorded 14 foals (25 eyes) in 167 neonatal foals, which is a very similar incidence. The incidence of papilloedema in human neonates is much lower than this, but has been associated with intracranial pressure changes (Davies, Robinson, Scopes, Lizard and Wigglesworth, 1972). One difference between the species in incidence may be related to the soft, flexible nature of the human neonate's skull, allowing increased intracranial pressure to result in bulging of the anterior fontanelle before the papilloedema is detected (Wigglesworth and Pape, 1979).

The majority of foals in this survey had a bilateral occurrence of papilloedema, which is the most common presentation if it is derived from increased intracranial pressure, although Palmer (1975) does record unilateral lesions due to one-sided optic nerve pressure or unilateral cerebral hemisphere lesions. The eye and sex distribution in Frauenfelder's studies were even, but the most severe forms were seen in females. This survey showed a significant bias towards females in both papilloedema and retinal haemorrhages (see Chapter 16). Frauenfelder (1983) speculated that this might be due to decreased birth weights in filly foals. In this survey, however, it has already been shown that birth weight was not related to sex, and further, the incidence of papilloedema was higher in larger body weight foals. No bias towards either sex has been shown in human neonatal studies and the reason for its occurrence in this study is not understood.

There was a significant statistical relationship of papilloedema and abnormal foal behaviour in this survey. All 3 abnormal foals had Group 2 abnormalities, 2 of which had obvious neurological changes related to central nervous system pathology. All of these foals had distinct papilloedema, the best example being the foal with Neonatal Maladjustment Syndrome. As previously stated by Munroe and Barnett (1984), the return of the optic disc to normality shadowed the improvement in behavioural patterns of the foal. Frauenfelder (1983) had similar findings and pointed out that since the pathophysiological basis of NMS is believed to be cerebral oedema and/or haemorrhage leading to ischaemic necrosis, the incidence of papilloedema should be higher in these affected foals. Presumeably, those foals with papilloedema and no neurological signs, had degrees of cerebral oedema or increases in intracranial pressure not serious enough to cause nervous system damage or dysfunction.

In this survey the incidence of papilloedema appeared related to Category 3 and 4 foalings and multiparity. Similar findings have already been noted in the incidence of subconjunctival haemorrhage. Multiparity is associated with increased birth weight in this survey but not Category 3 or 4 foalings. Further, it has already been noted that increased birth weights are overrepresented in the papilloedema group. It seems likely, therefore, that a combination of birth weight, relative foetal oversize (possibly of bone size but not weight), and speed and magnitude of delivery forces, may lead to excessive mechanical stresses on the head and thorax of the foal (Palmer and Rossdale, 1975). This could then lead to increased venous pressure, and/or hypoxia, and concommittant cerebral oedema/increased intracranial pressure. A similar sequence of events has been proposed for the pathophysiology of neonatal retinal haemorrhages in the equine (Munroe, 1988) and will be discussed further in Chapter 16. Interestingly, the incidence of retinal haemorrhages in this survey was strongly related to the finding of papilloedema, which has been recorded by Frauenfelder (1983). Focal retinal haemorrhages, especially around the disc, have also been recorded in calves with acquired hypovitaminosis A and papilloedema (Miller and Gelatt, 1991).

Frauenfelder (1983) has already suggested that the colour of the optic disc could be a useful sign for the detection of mild degrees of cerebral oedema before obvious papilloedema is present. Certainly in this survey, on average the discs with papilloedema were more congested (red-pink) than normal discs, and had more of an homogenous character. The latter is probably related to oedema of the optic nerve head already noted by Gelatt (1982) in papilloedema in the adult horse. Equally, congestion and tortuosity of retinal vessels, on and off the optic head, have been recorded in this condition in the horse (Gelatt, 1982) and calf (Miller and Gelatt, 1991). The colouration of the disc and retinal vessel pattern returned to normal as the papilloedema resolved in the animals in this survey, as in Frauenfelder (1983).

b) Retinal Vessel Pattern.

The majority of foals in this survey had a retinal vessel pattern as previously described for both the foal and the adult horse in the literature (Gelatt, 1982; Munroe and Barnett, 1984). This consisted of between 40 and 60 small vessels radiating from the disc in all directions, but less so in the area of the embryonic fissure. In none of the foals in this survey were increased numbers of vessels detected, which is not surprising considering that this has yet to be recorded in the equine ophthalmology literature to date. Decreased numbers, or attenuation of vessels, have a much greater pathological significance and possible consequences on vision (Matthews *et al*, 1990b). The single foal in this survey with a decreased number of vessels was affected by a congenital chorioretinitis, vitreal debris, and lens cataracts. Matthews *et al* (1990b) have already stated that such a peripapillary retinal pigment epithelium/choroidal degeneration may show attenuation or loss of retinal vasculature. This case, besides having less vessels, also had enlargement of their diameter, possibly in an attempt to compensate for decreased numbers, or due to abnormal formation during the foetal period. 7 other foals had retinal vessels of increased diameter which may have been related to the overrepresentation of retinal haemorrhages and papilloedema in this group. As previously stated, both these processes can lead to retinal vessel congestion and increased tortuosity (both intra- and extra-disc), and these changes were seen in a number of foals in this survey. One foal had haemorrhage around a dorsal retinal vessel associated with a mild papilloedema, and may be similarly connected. Increased tortuosity of retinal vessels, outside and inside the disc, maybe a normal variation in some foals and has been recorded previously (Munroe and Barnett, 1984; Barnett and Bedford, 1985; Matthews *et al*, 1990a). Increased visible length of retinal vessels could also be a normal variant, and may, along with increased diameter, and especially increased visualisation of vessel pattern, be related to tapetal/non-tapetal fundic colouration. Optic disc colour may also have a similar effect, in the pale pink category at least, by highlighting the origin of retinal vessels and their visualisation. Red-pink disc colouration may have a connection, through papilloedema and vessel congestion, with increased vessel tortuosity, vessel diameter, and more distinct vessel pattern. Of the 2 foals with a less distinct pattern, one had no obvious fundic problems and was probably a normal variation, possibly related to fundic pigmentation and ease of identification. The other had papillary and peripapillary oedema, making the focusing of the ophthalmoscope on the disc area and identification of vessels difficult.

There was, in general, no relationship between the retinal vessel pattern and any abnormality of the foal or vision. The high numbers of bilaterally symmetrical changes also reinforces this point. In conclusion, the majority of abnormalities of retinal vessel pattern were considered to be normal variations in individual foals, not related to any other ocular or systemic pathology.

c) Tapetal Fundus.

The variability of the appearance of the fundus, especially the tapetal region, is well known in the foal (Latimer *et al*, 1983; Munroe and Barnett, 1984) and adult horse (Gelatt, 1969; Barnett, 1972; Matthews *et al*, 1990a). The tapetal fundus was present in all recordable foals with bilateral symmetry in appearance in all foals, except one. 16 different categories were used, often in combination, in an attempt to describe the colour of the tapetal fundus.

The most common tapetal colours in this survey were yellow-green, green with a yellow periphery, and yellow-orange with a green periphery. This is confirmation of previous results in a mixed breed survey of foals (Latimer *et al*, 1983), and is in contrast to that found in adult Thoroughbreds, where a blue-green tapetal colouration is most common (Latimer and Wyman, 1985; Lavach, 1990). Only 8 foals were found in this survey to have blue pigmentation in their tapetal fundus, usually mixed with various shades of green. Whole coloured green and yellow were found in 8 and 7 foals respectively in this survey, colours which have been recorded before in the foal (Munroe and Barnett, 1984).

The variation in tapetal fundic colour has been suggested to have strong linkage to coat colour in the horse (Gelatt, 1982; Munroe and Barnett, 1984; Matthews *et al*, 1990a; Rebhun, 1991). In this survey no such correlation was found statistically. One reason may have been the small numbers of foal coat colours recorded other than chestnut and bay. Gelatt (1969 and 1982) and Rebhun (1991) stated that most chestnut and bay horses have a yellow-green tapetal fundus, and it is the black, grey and palomino coat colours which show greatest variation from this standard colour. As these coat colours were uncommon, or absent, in this survey, the statistical analysis was unlikely to make a meaningful connection between coat colour and tapetal fundus colour. The partial or complete albinism (Barnett, 1972; Gelatt, 1982; Munroe and Barnett, 1984) seen in the tapetal fundus in the palomino, cream, or other light-coloured hair coats were also not recorded because of the narrow band of whole coat colours seen in Thoroughbreds in this survey and generally. The well-demarcated zones of tapetal colour variation seen in some breeds, including the Standardbred (Latimer *et al*, 1983), possibly reflecting variations in relative thickness of the tapetum, were not seen in this survey.

Dorsal pigment mottling was seen in 99.5% of foals in this survey, and in occasional foals towards the periphery of the tapetal fundus. It has been recorded in the foal (Munroe and Barnett, 1984) and adult (Barnett, 1972; Matthews *et al*, 1990a) previously, and is considered to be areas of the tapetal fundus where the tapetum is thinning or absent, allowing the pigmented retinal epithelium to be seen. No clear border between the mottled and coloured fundus was usually evident in the foals in this survey and, by definition, the tapetum absence or decrease is patchy and uneven. The mottling was dark brown in 158 foals, but grey-brown in 8. This variation in colour did not appear to be related to overall tapetal fundus colour, whereas absence of, or decrease in, mottling was strongly associated with yellow tapetal colour. The decrease in mottling may have been due to decreased retinal epithelium pigmentation or less thinning of the tapetum. The nasal quadrant pigment mottling seen consistently in one survey (Latimer *et al*, 1983) was not recognised as a particular entity in this survey.

Stars of Winslow were recorded in all foals where the fundus was visible. They consisted of discrete dots distributed evenly throughout the tapetal fundus. Their colour reflected the overall tapetal fundus pigmentation with all but the yellow and yellow-orange categories having black dots, and the lighter fundi reddish-brown. In the yellow tapetal fundi the dots appeared more prominent, probably due to a greater contrast of colours. In those areas of tapetal thinning dorsal to the disc, the stars of Winslow were less obvious.

The relationship of tapetal fundic colouration to other pigmented areas of the neonatal eye was interesting, particularly since it was not possible to relate tapetal and coat colour, and many other parts of the eye have already shown a correlation with coat pigmentation. Green-yellow tapetal fundus was related to whole coloured pink nictitans, more obvious pectinate lines, dark brown and grey-brown iris colour, dark brown non-tapetal fundus, dorsal disc depigmentation, and choroidal vessel presence. Yellow-green colouration was also associated with similar iris and non-tapetal colours, but not choroidal vessel presence. Yellow-orange had higher numbers of pink, black edge nictitans, light brown-grey non-tapetal fundus, but a lower incidence of pectinate lines and choroidal vessels. Yellow tapetal fundus was strongly related to the incidence of choroidal vessels.

The presence of choroidal vessels and dorsal-to-disc depigmentation was very strongly correlated and is discussed in later sections. The relationship of tapetal and non-tapetal colouration appears clearly to be related to the amount of pigmentation, with dark tapetal colours being associated with dark non-tapetal colours and *vice versa*. The connection of other pigmented areas of the eye with certain tapetal colourations may be on a chance basis, or reflect an overall affect of coat colour on ocular pigmentation. Therefore, despite no overall statistical relationship with tapetal colour, this manages to reverse the negative correlation in the larger colour groups.

Choroidal Vessels.

42 foals in this survey had visible choroidal vessels in the fundus. Of these 42 foals, 38 had a bilaterally symmetrical incidence, although slight variations between sides did exist, and 2 each were unilateral right and left. The vessels were only seen in the area immediately dorsal to the optic disc running through the border into the tapetal fundus The presence of the vessels was almost 100% related to dorsal-to-disc depigmentation. Latimer *et al* (1983) in foals, and Matthews *et al* (1990a) in adults, have already recorded similar findings, due to a relative thinning of the tapetum and accompanying retinal pigment dilution in the non-tapetal fundus. This is most commonly observed, as in this survey, in the suprapapillary region. The degree and extent of thinning and depigmentation varies between animals, and is responsible for the number and clarity of choroidal vessels seen. Latimer *et al* (1983), in a group of foals, recorded these changes as red or pink streaks, but stated that discrete choroidal vessels were infrequently seen in the hypopigmented area adjacent to the disc. The results of this survey disagree with these findings, since parts of choroidal vessels were visible in all 42 foals, 40 of them in the dorsal-to-disc depigmented area. 88% of the vessels seen were red or pink in colour, the rest appeared purplish or mauve. The variation in colour was related to the degree of depigmentation, with those of red-pink colour being associated with less pigment and an overall pink-red background streak. Some choroidal vessels were visible, but less obviously, without these red "streaks" and were then more purple in colour and less detailed. A high percentage of vessels were visible immediately above and next to the disc. Where the shape of the vessels were recorded, then both longitudinal and end-on types were noted. A higher number of end-on vessels was seen in the tapetal fundus, particularly as the distance from the disc increased. It is not clear whether these were the isolated foci of a bluish-purple appearance recorded by Matthews *et al* (1990a) in the tapetal fundi of grey horses, and said to be related to minor anomalies of blood vessels in the choriocapillaris. The so-called streaks recorded by Latimer *et al* (1983) were less obvious in this survey, were more restricted in extent and always contiguous with the disc, and did not extend into the non-tapetal fundus.

Most of them took on a lighter hue of the underlying tapetal and non-tapetal colouration.

Besides the relationship of choroidal vessels to dorsal-to-disc depigmentation, there were other correlations with tapetal/non-tapetal colours, optic disc colours and border type. Perhaps the most interesting of these relationships was that with atypical colobomata. It possibly indicates that local tapetal thinning and retinal pigment dilution in the peripapillary region is related to the retinal pigment epithelium defects in the colobomata. The two being the same but occurring in separate areas and to different degrees. There was no evidence from this survey that the presence of choroidal vessels in the peripapillary region, without the signs of other fundus pathology, was related to any foal parameter or ocular defect. The relationship of choroidal vessel incidence to coat colour, nictitans pigmentation and iris colour did not quite fit into the picture that was built up of the connection between coat colour and ocular colouration. The relationship with bay coat colour, pink/black edge nictitans, and green-yellow or green-blue tapetal colouration was all consistent, but was countered by a grey-brown iris and grey-brown non-tapetal fundus correlation that was opposite to expectations. Further clarification by examining greater numbers of foals is required to assess the relevance of these factors.

d) Non-Tapetal Fundus.

Border.

There was an obvious demarcation between the tapetal and non-tapetal areas of the fundus in all the foals in this survey, although there were grades of variation within this. In general, the border or junction was most obvious in the darker categories of tapetal and non-tapetal colouration. In the vast majority of the foals (87%), this division between the two areas of fundus was a straight, sharp change or line. In 21 foals (12.5%) the border was more "ragged" or irregular in appearance, with either a gradual change from tapetal to non-tapetal colouration, or small areas of tapetal colouration present further in the non-tapetal zone and *vice versa*. This irregular delineation between the two parts of the fundi has been recorded previously in foals (Latimer *et al*, 1983; Munroe and Barnett, 1984) although, rather surprisingly, not in adults. It is almost certainly due to the varied pigmentation of the retinal pigment epithelium in this transition zone, and the differences in tapetum fibrosum thickness and extent. In 3 foals part of the border was indistinct. In all cases this was in the area immediately over the optic disc. It was difficult to decide whether these foals were actually examples of the ventral dipping of the tapetum towards, or to, the dorsal margin of the optic disc, previously recorded by Latimer *et al* (1983). The cases in this survey were probably examples of degrees of variation of the same condition seen by Latimer *et al* (1983), and may be related to the dorsal-to-disc depigmentation so commonly seen in adult horses and foals, and discussed in the next section.

Atypical colobomata were recorded in the border region in 16 foals and are discussed under congenital conditions of the fundus. They were more common in the border region than elsewhere and required careful differentiation fom tapetal islands and the ragged border affect already mentioned. They differed in colour: usually white or blue-white as opposed to relevant tapetal colour; and shape: usually more circumscribed and distinct, and occasionally round or "cobblestone".

The only relationship of border type with any ophthalmic category of any note is that with non-tapetal fundic colouration. The straight border type was more common in the dark brown non-tapetal fundus, and the ragged with the grey-brown non-tapetal fundus, especially with atypical colobomata. Part of this may be due to the previously noted increased demarcation in dark tapetal/non-tapetal colour fundi (optical affect). Of greater interest, is the possibility that variations in RPE and tapetum may manifest as both ragged border and atypical colobomata (possibly as dorsal-to-disc depigmentation as well - see next section), especially in foals with less pigment in their non-tapetal fundus. Perhaps of more interest to the clinician and owner is whether they represent just normal variations with no affect on vision. Certainly this appears likely, based on this survey's results, bearing in mind its limitations.

Colour.

This survey confirmed that the majority of foals have dark brown non-tapetal fundi (Latimer *et al*, 1983; Munroe and Barnett, 1984; Blogg, 1985). This is also the most common colour in the adult horse (Gelatt, 1969; Barnett, 1971; Rebhun, 1991). Latimer *et al* (1983) also found a few foals with reddish-brown colour which was not confirmed in this survey. 20% of foals, however, did have a grey-brown colouration, 3 foals were much darker and almost black, and 1 foal had a very unusual grey-green colour. No examples of subalbinism or albinism (Gelatt, 1982; Munroe and Barnett, 1984; Rebhun, 1991) were recorded in the non-tapetal fundus of the foals in this survey, probably, as already suggested, due to the narrow band of whole colours of darker pigment seen in the Thoroughbred generally, and confirmed in this survey. Some of these coat colours are, however, associated with subalbinism.

Appearance.

The majority of foals in this survey had a non-tapetal fundus that was homogenous in colour and appearance, although a very large minority had less pigmentation immediately dorsal to the optic disc. 11% of foals had atypical colobomata throughout the non-tapetal fundus and are discussed elsewhere. The light grey streaks arcing nasally and temporally away from the ventral disc margin seen by Latimer *et al* (1983) were not confirmed. These striae were considered to represent altered reflectivity of the nerve fibre layer, due to concentrations of retinal vessels, or subtle extension of myelin into the nerve fibre layer. Other workers have not found them, although Gelatt (1982) did find similarly described areas immediately adjacent to the disc. One foal had a variation of the non-tapetal appearance thought to be a retinal pigment epithelium and choroidal degeneration and is discussed later.

Overall Description.

The combination of colour and appearance lead to an overall description of the non-tapetal fundus. 11 categories were the result of this combination and some of them contained only one or two foals. The large numbers of foals with dorsal-to-disc depigmentation have been recorded before in foals (Latimer *et al*, 1983; Munroe and Barnett, 1984) and adults (Gelatt, 1969; Barnett, 1971; Matthews *et al*, 1990a). The variation in extent of this depigmentation to involve, in some cases, both tapetal and non-tapetal fundi, was noted in this survey, although the area just dorsal to the disc and below the border was the most common type. The degree of tapetal hypoplasia and pigment dilution varied, but in the majority of cases it was enough to expose the underlying choroidal vasculature. In 1 case it was so extensive as to surround the entire optic disc. Latimer *et al* (1983) described 5 similar foals. This dorsal-to-disc depigmentation was relatively more common in the grey-brown non-tapetal fundi and was strongly related to the atypical colobomas. No tapetal islands, as described by Gelatt (1982) and Latimer *et al* (1983) were detected. The connection of ragged border, atypical colobomas, and dorsal-to-disc depigmentation has been made earlier and none of these findings appear to be associated in this survey with any foal or ophthalmic parameter.

Dark brown/homogenous and dark brown/dorsal-to-disc depigmentation were the most common terms to describe the non-tapetal fundus in this survey. Foal coat colour and non-tapetal fundus colour/appearance are related in this survey (in contrast to tapetal colour) and this has been noted previously in adults, although not foals (Gelatt, 1969; Gelatt, 1982; Rebhun, 1991). Tapetal and non-tapetal colouration and appearance are also correlated in this survey. The dark brown/homogenous and dark brown/dorsal-to-disc depigmentation non-tapetal fundi are more commonly found in bay foals, with yellow-green/dorsal mottled and green-yellow/dorsal mottled tapetal fundi, respectively. Chestnut and grey foals are more likely to have brown-grey/+/-dorsal-to-disc depigmentation non-tapetal fundi with a yellow-orange-green border/dorsal mottled tapetal fundi. Further analysis of ocular colouration and non-tapetal fundus colour and appearance reconfirmed the developing interrelationships which have appeared as this survey was analysed. Nictitans and iris colour were related to non-tapetal fundus description through the common denominator of coat colour. Dark brown/homogenous non-tapetal fundi are more commonly associated with pink/black edge nictitans and dark-brown iris, whereas grey-brown +/- dorsal-to-disc depigmentation with whole-coloured pink nictitans and grey-brown iris.

15.32 Congenital Abnormalities of the Fundus.

Although the incidence of fundic abnormalities appears to be high in this survey, only one of the foals had an apparent visual deficit. This was a blind foal with NMS and retinal haemorrhages, which recovered within 3 days and had no permanent ocular or visual disabilities. Both retinal haemorrhages and atypical colobomata have been called incidental findings or anomalies in the literature, and whether they belong to this group will be discussed further.

Atypical Colobomata.

No true colobomata were recorded in this survey, but 18 foals were found with atypical colobomata. The majority of lesions were in the thin area of non-tapetal fundus between the level of the disc equator and the horizontal border between the tapetal and non-tapetal fundi. 9 of the foals had a peripapillary location in this narrow band, whilst the rest were spread out along the border, more commonly on the temporal side of the disc. None of the lesions bordered the optic disc as described by Matthews *et al* (1990a). Only 2 foals had colobomata in the main part of the non-tapetal fundus. None of the colobomata were in the plane of the optic fissure which distinguishes them from true colobomata.

There were differences in incidence between eyes but in general there appeared to be no significant bias towards unilateral or bilateral incidence.

Previous reports of these lesions in the equine ophthalmology literature are confirmed by these findings (Szutter, 1962; Rubin, 1974; Rebhun, 1983; Matthews *et al*, 1990a). Koch *et al* (1978), in a survey of mainly Thoroughbred foals between 0-30 days, found the highest incidence of abnormalities to be pigment changes in the fundus, of which 21 of 82 foals had what they described as atypical colobomata. They described them as areas lacking pigment without evidence of inflammatory changes. They dismissed the possibility of post-inflammatory scars because of the absence of inflammatory disease. However, Latimer *et al* (1983) in describing similar lesions in 3 of their survey of 144 older foals, were unable to decide whether they represented absence of pigment, atypical colobomata cellular infiltration, or a focal degeneration scar. They suggested that histopathology would be required to differentiate these possibilities. Riis (1981) was unable to detect any inflammatory lesions histologically. Matthews *et al* (1990a) were more definite in their statement that they represent mainly RPE involvement, with the possibility of the choroidal and neurosensory retina changes as well in some cases. In none of the cases in this survey was there any evidence of inflammation in the posterior segment and the lesions appeared quiescent. It seems unlikely that such a large number of foals should have developed congenital inflammatory lesions, leading to these small and discrete colobomata, without other defects or signs being present.

These colobomata are notoriously varied in appearance in the previous reports and this was confirmed by this survey. The majority of foals had single or double lesions with considerable bilateral symmetry, where applicable. The shape of colobomata varied, but most of the foals had either small round discrete, or medium-sized ragged or uneven lesions with, again, reasonable bilateral symmetry. The lesions were well demarcated but did not have a surrounding zone of hyperpigmentation as described by Matthews *et al* (1990a). In those colobomata close to the optic disc traversing retinal vessels appeared normal. In none of the foals with colobomata in this survey were there any visual deficits and, although it has been stated that normal photoreceptor function will be compromised in these areas, they are so small and widely dispersed as to be insignificant.

The colour of the colobomata was recorded to be light blue or blue in all the foals in this survey, as previously reported by Rebhun (1983). Koch *et al*

(1978) and Latimer *et al* (1983) considered them to be usually white. Koch *et al* (1978) did, however, say that they would be pigmented if tapetal tissue was present. Whether this would then be a tapetal island as described by Latimer *et al* (1983) is unclear. The colour of the lesions in this survey may have been related to tapetal/non-tapetal fundic colour, but this was not clear. It would seem likely that most of the colour variation is related to the degree of pigment epithelium and choroid loss.

The incidence of atypical colobomata in this survey was statistically related to the occurrence of a ragged border between the two fundi, and dorsal-to-disc depigmentation. These are two normal variations in the equine fundus associated with variations in the tapetum and retinal pigment epithelium. It seems conceivable, to this author, that atypical colobomata, focal non-pigmented spots, tapetal islands or whatever anybody else wishes to call them, are all normal variations in the degree of retinal and choroidal pigmentation, and tapetal extent. These variations presumably occur during embryogenesis, probably as minor abnormalities and normal variations, and are most likely to occur near to the border and peripapillary region where there is the greatest potential for pigment variation.

Congenital Chorioretinitis.

The foal with peripapillary and choroidal RPE degeneration (Butterfly Lesion) is an example of a lesion seen commonly enough in the adult horse (Barnett, 1972; Gelatt, 1982; Lavach, 1990; Matthews *et al*, 1990a & b), but rarely in the neonatal foal. Matthews *et al* (1990a & b) describes them as unilateral discrete areas of pigment loss and focal hyperpigmentation, occurring lateral and medial to the disc margin. The choroidal vasculature may be evident with occasional focal lesions outwith the peripapillary region. Attenuation of retinal vasculature may be observed, but the lesions are nearly always inactive. Vitreal flare or debris, and diffuse posterior capsular cataracts are also not uncommonly observed in association. This description fits exactly that which was seen in this foal.

It has been suggested that the peripapillary choroidal pathology in the horse derives from exposure to exogenous blood-borne antigens (Williams *et al*, 1971, cited by Matthews *et al*, 1990b). Whether such an exposure occurred in this foal whilst *in utero* is not known, but Rubin (1974) and Riis (1981) have reported focal depigmentation in the non-tapetal fundus in foals born to mares infected by respiratory infections. This mare did have an episode of abdominal pain 4 weeks before foaling, which was not treated. No other abnormalities occurred during pregnancy. It seems unlikely that the lesions were derived from a period as close to parturition as 28 days, since they were quiescent at birth and the nuclear lens cataract is likely to have developed much earlier in the life of the foetus. Whatever caused the lesion was capable of generating a serious posterior segment inflammation which, apparently, then spontaneously resolved.

Retinal Haemorrhages.

The large number of foals in this survey with retinal haemorrhages are considered in detail in the next chapter.

CHAPTER 16.

RETINAL HAEMORRHAGES.

16.1 INTRODUCTION AND REVIEW OF LITERATURE.

16.11 Retinal Haemorrhages in the Equine.

Retinal haemorrhage is a non-specific lesion that may be associated with inflammatory disease, retinal detachment, neoplasia, trauma, clotting disorders, chorioretinitis, and other conditions (Latimer and Wyman, 1985).

Small retinal haemorrhages have been observed in foals suffering from the Neonatal Maladjustment Syndrome (NMS) (Mahaffey and Rossdale, 1957; Rossdale, 1969, 1972a and 1972b; Barnett, 1975; Rossdale and Ricketts, 1980; Latimer and Wyman, 1985; Whitley, 1990) These haemorrhages were seen at 1-2 days of age and resolved within a few days (Barnett, 1975). Affected foals may also show pupillary abnormalities, being dilated and non-responsive, miotic, or asymmetric (Latimer and Wyman, 1985). Apparent blindness accompanies a variety of neurologic and odd behavioural signs including convulsions, opisthotonus, erection of tail, hyperexcitability, coma, inability to stand, dog-sitting stance, frantic galloping movements, mouth breathing, teeth grinding, barking, sneezing, and loss of suck reflex (Rossdale and Ricketts, 1980; Clement, 1987; Mayhew, 1988 and 1989; Green and Mayhew, 1990). Scleral splashing, or subconjunctival haemorrhage, was also observed in association with this syndrome (Rossdale, 1969; Barnett, 1975). More recently, Munroe and Barnett (1984) suggested that papilloedema and changes in optic disc colouration seemed to be more closely related to the cerebral oedema seen in these cases, and that not all cases of NMS had retinal haemorrhages. Resolution of the papilloedema, and occasional accompanying anisocoria, did appear to closely parallel the improvement in clinical and neurological status of the foal (Munroe and Barnett, 1984; Munroe, 1988). Moreover, it has been the author's experience that retinal haemorrhages are commonly encountered in neonatal foal examinations in otherwise perfectly normal foals, and this has prompted the statement, by himself and others, that neonatal retinal haemorrhages in the foal are of no clinical significance (Frauenfelder, 1983; Munroe and Barnett, 1984; Munroe, 1988).

The actual aetiology of retinal haemorrhages in the equine neonate has not been clarified, but many workers state that they are due to the trauma of birth (Bistner, 1984; Lavach, 1990; Whitley, 1990). Munroe (1988) put forward the theory that they were due to a combination of anoxia/asphyxia and increased intraluminal pressure occurring at birth.

The level of the haemorrhage in the equine neonate has not been studied histologically but Bistner (1984) stated that it develops from the choroidal circulation. Matthews *et al* (1990) considered it to occur within the subretinal space or at the level of the choriocapillaris. Lavach (1990) was more catholic in his views, when he suggested that the retinal haemorrhages could occur in the vitreous, retina and/or choroid.

All authors agree that they resolve within 7-10 days and are not associated with any long term visual or neurological deficits (Barnett, 1975; Bistner, 1984; Munroe and Barnett, 1984; Lavach, 1990).

16.12 Perinatal Retinal Haemorrhages in the Human.

Retinal haemorrhages have also been recorded in the newborn human infant and were first described as long ago as 1881 by Konigstein (von Barsewisch, 1979). Since then a very large number of reports have been published describing the incidence, aetiology, morphology, significance and long-term effects, and pathogenesis of this phenomenon (Richman, 1936; Kauffman, 1958; Giles, 1960; Neuweiler and Onwudiwe, 1967; Critchley, 1968; Baum and Bulpitt, 1970; Sezen, 1971; Planten and Schaaf, 1971; Bergen and Margolis, 1976; Jayanthi and Aurora, 1978; von Barsewisch, 1979; Levin *et al*, 1980; Maltau and Egge, 1980; Egge, Lyng and Maltau, 1981; Schoenfeld *et al*, 1985; Zundert *et al*, 1986; Svenningsen and Eidal 1987 and 1988; Bist *et al*, 1989; Kaur and Taylor, 1990 and 1992).

This is a usually benign form of haemorrhagic retinopathy presenting as both intra- and extra- retinal haemorrhages (von Barsewisch, 1979) of different morphology located in the posterior pole or periphery (Kaur and Taylor, 1990). The reported incidence varies enormously, from 2.6 to 50% (Schenker and Gombos, 1966; Critchley, 1968; Baum and Bulpitt, 1970; Sezen, 1971; Bergen and Margolis, 1976; Besio *et al*, 1979; von Barsewisch, 1979; Levin *et al*, 1980; Egge, Lyng and Maltau, 1980 and 1981; Van Zundert *et al*, 1986; Govind, Kumari and Lath, 1989). Reasons for this include the variable time before fundus examination after birth, the technique of examination, the experience of the examiner, the method of delivery, and perinatal and maternal history (Kaur and Taylor, 1990 and 1992).

The exact mechanism by which neonatal retinal haemorrhages occur is not clear, but proposals include changes in blood viscosity (Baum and Bulpitt, 1970); prostaglandins in the foetal circulation (Schoenfeld *et al*, 1985); unequal pressure distribution during birth with a sudden release leading to a rapid change in intracranial pressure (Critchley, 1968; Levin *et al*, 1980; Maltau, Egge and Moe, 1984); increased intravascular pressure (Planten and Schaaf, 1971; Goetting and Sowa, 1990); direct trauma (Lie Kay Hoo, 1973); and anoxia, vessel dilation and increased intracranial pressure (von Barsewisch, 1979).

The retinal haemorrhages in newborn infants usually resolve within a few days (Baum and Bulpitt, 1970; Besio *et al*, 1979; Kaur and Taylor, 1992) and follow-up studies have not revealed any long term defects (Bonamour, 1949; von Noorden and Khodadoust, 1973; Lowes, Ehlers and Krarup Jensen, 1976; Levin *et al*, 1980; Kaur and Taylor, 1992). Some authors have suggested that they may reflect intracranial haemorrhage and minimal brain damage (Critchley, 1968; Egge *et al*, 1981; Maltau, Egge and Moe, 1984), but examination of affected babies by histology and CCT scanning has not confirmed this (Skalpe, Egge and Maltau, 1982).

The morphology of the haemorrhages has been described and argued over in the human literature for some time. Baum and Bulpitt (1970) divided them into splinter, flame, lake and dense blob haemorrhages. Critchley (1968) in reviewing the work up to this time, separated them into flame-shaped, small round or elongated deep, large round, and subhyaloid haemorrhages. Egge, Lyng and Maltau (1980) graded them based on the area of retina covered in relation to optic disc size. Their four grades were: grade 0, no bleeding; grade 1, small haemorrhages; grade 2, more extensive haemorrhages, though not exceeding the diameter of the disc; grade 3, fundi with haemorrhage larger than the disc, plus occasional pre-retinal haemorrhage. Von Barsewisch (1979), in his extensive work on retinal haemorrhages in the newborn, classified them as: stage I, flame-shaped haemorrhages in the nerve fibre layer of the retina; stage II, round haemorrhages of the internal granular layer; stage III, haemorrhage as in II but involving the macular region; stage IV, dark red epiretinal haemorrhages; stage V, as IV but with marked congestion of retinal veins. Severity increased from stage I to V. Kaur and Taylor (1990 and 1992) stated that the shapes and colour of retinal haemorrhages is determined by the level or levels of the retina affected, and they are often a mixture of splinter-shaped, flame-shaped and dot/blot haemorrhages (intraretinal).

16.2 RESULTS AND STATISTICS.

16.21 Incidence.

Retinal haemorrhages were noted in 27 foals (16%) and 39 eyes (12%), in the 167 foals (334 eyes) where recording was possible. 2 New Zealand and 25 U.K. bred foals had retinal haemorrhages. Statistically there was no significant difference in the incidence in the two countries.

16.22 Eye Distribution.

The distribution between right and left eyes is shown in Table 16.1.

	L eye only	R eye only	Bilateral
Foals	6	9	12
Eyes	6	9	24
Total Eyes Affected	18	21	

12 foals (44%) had a bilateral incidence of retinal haemorrhages (figures 186 & 191), with 6 foals (22%) left eye only (figure 189), and 9 foals (33%) right eye only (figure 190). In total 18 left eyes (46%) and 21 right eyes (54%) were affected by retinal haemorrhages.

16.23 Sex Distribution.

The distribution between sexes in retinal haemorrhage incidence is shown in Table 16.2.

	Female	Male	Total
Left	2	4	6
Right	6	3	9
Bilateral	8	4	12
Total	16	11	

16 female foals (59%) and 11 male foals (41%) had retinal haemorrhages. Statistically there appears to be a significant difference in sex distribution. Comparison of sex and eye distribution shows that twice as many right and bilateral haemorrhages occur in females, whereas the opposite is true in left haemorrhages. The type and number of haemorrhages did not have any relationship to sex.

16.24 Morphology of Retinal Haemorrhages.

The number, type, distribution over the tapetal fundus, and stage of development of retinal haemorrhages are recorded in Tables 16.3, 16.4, 16.5,and 16.6 respectively

Table 16.3.

a) Numbers of Haemorrhages.

	Left	Right	Bilateral	Eyes	Foals
1-5	4	5	8	21	17
6-10	1	1	4	7	6
>10	1	3	6	11	10

6 foals in the bilateral group had differences between eyes in the number of haemorrhages.

In table 16.3, 17 foals or 21 eyes (54%) had numbers of haemorrhages between 1 and 5 (figures 167, 181 & 192), 6 foals or 7 eyes (18%) had 6-10 (figures 179 & 191), and 10 foals or 11 eyes (28%) had greater than 10 (figures 189, 190, 193 & 197). In some of this latter group up to 20 or more were sometimes present (figure 189). In 6 foals the numbers of retinal haemorrhages varied between the bilaterally affected eyes. All of these foals, except 1, also had variation between eyes in type of haemorrhage, and 4 foals also had bilaterally variable distribution patterns. Bilateral haemorrhages appeared more likely as the numbers of haemorrhages increased.

b) Type of Haemorrhage.

Table 16.4.

	Left	Right	Bilateral	Eyes	Foals
Small, punctate	1	4	6	15	11
Large, splashes	3	4	6	14	13
Small, splashes	1	1	4	8	6
Mixed Pattern	1	0	2	3	3

Four groupings were used to classify the retinal haemorrhage type in table 16.4. 11 foals or 15 eyes (38%) had small, punctate haemorrhages (figure 190), whereas 13 foals or 14 eyes (35%) had the large, splash-like type (figure 167). Small splashes were seen in 6 foals and 8 eyes (figures 179 & 194), and a mixture of punctate and splash in 3 foals and 3 eyes (figures 159, 177 & 189). In total, 19 foals or 22 eyes (56%) had splash-like haemorrhages. There was considerable variation between eyes in some foals (6). 2 foals had punctate and large splash-like haemorrhages in opposite eyes; a further 2 had a mixed pattern in one eye and pure splash-like haemorrhages in the other. The type of haemorrhage does appear to marginally affect the distribution between left and right eyes. With splash haemorrhages it is more likely that an even left/right distribution will occur, with slightly more left eyes affected in the punctate group.

Statistically, it appears that small numbers of haemorrhages are more likely to be of the punctate type (both left and right eyes) whereas, as numbers increase especially above 10, then splash type haemorrhages start to predominate. The type of haemorrhage does not significantly affect the distribution within each eye, but there is a relationship between type and stage of development, with splash haemorrhages being overrepresented in the resolving category.

c) Distribution in Fundus.

The distribution of the retinal haemorrhages in the tapetal fundus is shown in table 16.5.

In the discrete category, 15 foals or 18 eyes (46%) had haemorrhages above the optic disc (figures 159, 181 & 192). This majority (18 out of 24 eyes) was in contrast to 2 foals or 3 eyes with nasal (figue 186), and 3 foals or 3 eyes with temporal distribution respectively.

Table 16.5.

		Left	Right	Bilateral	Eyes	Foals
	Above Disc	3	4	8	18	15
Discrete	**Nasal**	0	0	2	3	2
	Temporal	1	1	1	3	3
Widespread		1	3	6	13	10
Optic disc		1	1	0	2	2

All the widespread affected eyes (13 eyes or 11 foals) (33%), were seen in foals with 6 or greater haemorrhages (figures 179, 189, 190 & 195), whereas discrete distribution was related to low numbers of haemorrhages. 2 foals had haemorrhages affecting the optic disc (figure 167), both unilaterally, and only a single haemorrhage in each case. The split between left, right and bilateral incidence was not significantly affected by whether the haemorrhages were discrete or widespread, however, the left eye was underrepresented in the widespread group. 5 cases, as previously mentioned, had differences in distribution pattern in bilaterally affected eyes. The distribution of haemorrhages did not relate to their stage of development.

d) Stage of Development.

The subjective assessment of the stage of development of haemorrhages is shown in Table. 16.6.

Table 16.6.

	Left	Right	Bilateral	Eyes	Foals
Acute (red)	3	4	7	17	14
Resolving (purple)	3	5	9	22	17

17 eyes in 14 foals had acute haemorrhages (figures 167, 181 & 189), whereas slightly more, 22 eyes in 17 foals, had haemorrhages that were resolving (figures 177, 180, 190 & 195). 1 foal in the resolving group was recorded as having very early signs of resolution (figure 191). Several foals (4) had differences between eyes in stage of development, and some foals, even when examined within 24 hours of foaling, had evidence of early resolution. There appears to be no left, right or bilateral affect on stage of development. Statistically, there was no relationship between numbers of haemorrhages and stage of development.

16.25 Neonatal Foal Examinations.

The clinical findings of those foals with retinal haemorrhages were studied in detail and the data divided into sections. Comparisons were then made with equivalent data in the non-haemorrhage and haemorrhage groups.

a) Foal Size.

Table 16.7 summarises the foal birth weight in the retinal haemorrhage foals.

Birth weight (kgs)			Total
<45	Male	0	0
	Female	0	
45-50	Male	2	15
	Female	13	
51-56	Male	5	8
	Female	3	
>56	Male	4	4
	Female	0	

15 of the foals (56%) were within the 45-50kg category with 13 of these (87%) being female. 8 foals (29.5%) and 4 foals (14.5%) were in the 51-56kg and >56kg. categories respectively. None of the retinal haemorrhage foals had a birth weight less than 45kg, 62.5% in the 51-56kg category were male and 100% in the >56kg group. Overall there was a statistical relationship between foal size and retinal haemorrhages, although expected values in the <45kg and >56kg were less than 5, leading to some care being required in interpretation. Retinal haemorrhages in general, and especially in males, are more common in categories 51-56kg and >56kg than would be expected, and less common in <45 and 45-50 groups.

b) Foal Colour.

Table 16.8 shows the coat colours of the foals with retinal haemorrhages.

Bay	16
Chestnut	6
Grey	3
Brown	2
Black	0
Total	27

There was no significant relationship between coat colour and incidence of retinal haemorrhages.

c) Foal Behaviour.

The neonatal behaviour, including time to stand and suck, of foals with retinal haemorrhages is shown in Tables 16.9 and 16.10.

Table 16.9.

Normal	24
Group 1. Septicaemias	0
Group 2.	
NMS	1
Dysmature / Premature	0
Group 3. Developmental	2
Group 4. Immunological	0

Table 16.10

Time to Stand (hours)			Time to Suck (hours)		
<1	**1-3**	**>3**	**<2**	**2-4**	**>4**
25	0	0	20	3	2

Unattended Foaling	Unable to Stand/Suck
1	1

All the foals except 2 (93%), were standing within 1 hour of birth, and 20 of the 27 foals (74%) had sucked in less than 2 hours. 1 foal had an unattended foaling and was, therefore, not included in any group, but nevertheless was a normal foal. 1 other foal was unable ever to stand and suck due to a developmental limb problem, and was euthanased within 24 hours. Of the 2 foals that took greater then 4 hours to suck, 1 was normal and sucked on its own at 5½ hours, and the other was also clinically normal, but required nasogastric tubing at 4 hours before it sucked on its own.

24 foals were clinically normal (89%). 3 abnormal foals were recorded, 2 with developmental orthopaedic problems, 1 of which still stood and sucked in normal times, and 1 with Neonatal Maladjustment Syndrome. The latter stood and sucked before it convulsed.

There was no statistical relationship between abnormal foal behaviour, as determined by clinical examination or time to stand/suck, and the incidence of retinal haemorrhages.

16.26 Details of Maternal Findings at Pregnancy and Parturition.

The gestational and parturition findings of the mares producing foals with retinal haemorrhages were compared with the survey averages.

a)Parturition.

Table 16.11 summarisises the details of the foaling categories for the foals with retinal haemorrhages.

Foaling Category	1	2	3	4	5
	14	0	5	8	1

Foal 115 is included in category 3 and 4.

Those foals with retinal haemorrhages included in category 4 are shown in Table 16.12.

Table 16.12

Unattended Foalings	1 (114)
Prolonged First Stage	1 (99)
Standing Delivery	1 (109)
Obturator Paralysis	1 (112)
Early Placental Passage	1 (102)
Ventral Position, Anterior presentation turned by rolling mare in 1st. stage parturition	1 (108)
Vulva Stitched	1 (110)
Retained Placenta	1 (115)

In category 5, the 1 foal with retinal haemorrhages had a prolonged manipulation due to postural abnormalities.

Statistically, there is a significant association between foaling category and incidence of retinal haemorrhages. Less of the foalings were in the normal unassisted category and more were seen in the foetal oversize, miscellaneous, and prolonged manipulation groups. Within the miscellaneous group those appearing more frequently than expected include prolonged 1st. stage parturition, standing delivery, obturator paralysis after tight foaling, early placental passage, vulva stitched at parturition, retention of placenta and rolling of mare to correct a positional abnormality.

b) Gestational History.

Table 16.13 summarises the details of the pregnancy in the retinal haemorrhage foals.

			Overdue	>5<10	1
	Abnormal	6		>10<20	3
Pregnancy			Premature	>20	2
	Normal	21			

6 foals (22%) had abnormal pregnancies, all either overdue (15%) or early (7%) at parturition. Statistically, there was no significant relationship between abnormalities of pregnancy and incidence of retinal haemorrhage.

c) Parity.

Table 16.14 documents the parity of the mares producing foals with retinal haemorrhages.

Uniparous	5	
Multiparous	22	(81.5%)

No significant relationship exists between maternal parity and the incidence of retinal haemorrhages.

16.27 Ophthalmic Relationships.

The findings on ophthalmic examination of the retinal haemorrhage foals were compared with those without haemorrhages.

a) Examination Period.

Table 16.15 shows the time of first examination in those foals with retinal haemorrhages.

0-24	24-48	48-72	72-96 hrs.
23	3	1	0

85% of foals were examined in the first 24 hours.

In comparison to the general population, foals with retinal haemorrhages appear, statistically, to have been examined earlier than average in this survey. Since the rate of resolution of haemorrhages is partly related to time since birth, this earlier examination may have affected the number, type, and stage of resolution of the haemorrhages seen.

b) Vision.

Only one foal with retinal haemorrhages was blind (111). This foal was initially visual before convulsing and being treated with barbiturates. As previously reported, this foal also had anisocoria, papilloedema and a secondary entropion in the left eye. The resolution of the papilloedema and anisocoria paralleled the improvement of clinical signs. Although the retinal haemorrhages were resolving, they were still present when vision and neurological signs returned to normal. There was no significant relationship between lack of vision and retinal haemorrhages in this survey.

c) Reflexes.

There was no significant affect on menace, pupillary light reflexes, or PLR rapidity by the presence of retinal haemorrhages.

d) Scleral Haemorrhages.

4 foals (2.4%) had retinal and scleral haemorrhages, with 3 of these having bilateral scleral and retinal haemorrhages, and 1 foal bilateral scleral and unilateral (L) retinal haemorrhages.

Overall there was no significant statistical relationship between scleral and retinal haemorrahges using either a Chi-square or a Fisher's exact test. See Chapter 11.

e) Pupil.

The resting pupil size and shape, and its change after PLR stimulation are shown in tables 16.16 and 16.17.

Key C = Circular O = Oval E = Elliptical ? = Insignificant

Table 16.16

80 > ? **C > ?** 6	**80 > 70** **O > O** 4	**85 > 80** **C > C** 2	**70 > 60** **O > O** 2
70 > 50 **O > O** 2	**80 > 70** **C > E** 2	**60 > 50** **O > O** 1	**70 > 65** **O > O** 1
75 > ? **O > ?** 1	**70 > ?** **O > ?** 1	**65 > ?** **E > ?** 1	**70 > ?** **E > ?** 1
80 > 70 **C > O** 1	**75 > 70** **O > O** 1	**Anisocoria** 1	

Table 16.17

Resting Pupil Size	
90	0
85	2
80	13
75	2
70	7
65	1
60	1
Total	26

Stimulated Pupil Size	
90	0
85	0
80	2
75	0
70	8
65	1
60	2
50	3
Unknown	10
Total	26

Resting Pupil Shape	
C	11
O	13
E	2

Stimulated Pupil Shape	
C	2
O	12
E	2
?	10

Statistically there appears to be no significant difference in pupil size and shape, or anisocoria, between retinal haemorrhages and non-affected foals.

f) Hyaloid Apparatus.

There is no significant association between the presence of a hyaloid apparatus in either left or right eyes, and the incidence of retinal haemorrhages.

g) Optic Disc.

i) Colour.

The range of optic disc colour in the retinal haemorrhage foals is shown in Table 16.18.

Pale Pink	6
Pink	8
Red-Pink	13

13 foals (48%) had discs that were red-pink. Several of them had discs that could almost have been classified as red. There appears to be a very strong relationship between optic disc colour and incidence of retinal haemorrhages, specifically a marked decrease in pink and an increase in red-pink colouration.

ii) Shape and Character.

Optic disc shape was assessed as normal in 21 foals, and various other manifestations in 6 (see Chapter 15 on the optic disc). No connection was found between optic disc shape and retinal haemorrhages.

The character of the optic disc was assessed as homogenous in 13 foals (48%) and other combinations in 14 foals. There was a strongly statistically significant connection between the occurence of the homogenous disc character and retinal haemorrhages.

As previously recorded, 2 optic discs had single retinal haemorrhages unilaterally.

iii) Unfocusable Discs/Papilloedema.

4 foals had papilloedema, and 1 an unfocusable disc in the retinal haemorrhage foals. In 1 foal the papilloedema was unilateral, in the eye with retinal haemorrhges, otherwise the papilloedema and retinal haemorrhages were bilateral. As previously recorded, there is a strong connection between the incidence of papilloedema and retinal haemorrhages, although statistically the expected values are too low to be significant.

h) Retinal Vessel Pattern.

6 retinal haemorrhage foals had abnormal retinal vessel patterns, mainly increased tortuosity or size of vessels. This was not statistically related to the incidence of retinal haemorrhages.

j) Fundic Pigmentation.

There is no statistically significant relationship between the incidence of retinal haemorrhages in foals and tapetal or non-tapetal colouration, the presence of choroidal vessels, and types of border between the two parts of the fundus.

Case Resolution.

A number of the foals with retinal haemorrhage were followed closely to build up a picture of the resolution of the haemorrhages.

L = Left **R** = Right **RH** = Retinal Haemorrhage
PO = Papilloedema

105	Ex. +24hrs.	Bilateral, widespread, punctate, pale pink.	
		L 6-10	R >10 - 20
		Sl. indistinct.	
	+96hrs.	L eye No RH	R eye <5 RH
			small indistinct, pale pink.
107	Ex. +10hrs.	Bilateral, nasal, small (R) and large (L) splash, pink.	
		L 6-10	R 1-5
	+82hrs.	L eye 5 approx.	R eye no RH
		small, pale pink, nasal.	
	+178hrs.	No RH	
111	Ex. +10hrs.	Bilateral, discrete above disc, purple. PO. Blindness.	
		L eye punctate 1-2	R eye Large splash, 1 - 5.
	+21hrs.	As above. PO. Anisocoria.	
	+36hrs.	Nos. same, less distinct edge, paler colour. PO decreased.	
		No Anisocoria.	
	+60hrs.	As above. PO. R eye only. No Anisocoria. Normal foal.	
117	Ex +52hrs.	Bilateral, widespread, large splashes, >10	
		pale pink > purple.	
	+100hrs.	Nos. and distribution as above. Paler and edges less distinct.	
150	Ex. +11hrs.	Bilateral.	
		L > 10 widespread, mixed splash/punctate, red & purple.	
		R 3 - 4 dorsal-to-disc, splash (small), purple, resolving?	
	+36hrs.	L nos. decreased by 50%.	
		Haemorrhages spreading in size, diffuse at edge,	
		more purple > dirty blue brown, widespread.	
	+60hrs.	L and R nos. decreased by 60%, edges more diffuse mauve,	
		disappearing centripetally esp. L.	

16.3 DISCUSSION.

There are no detailed surveys of retinal haemorrhages in the neonatal foal in the veterinary literature, although Frauenfelder (1983, unpublished) did undertake a similar survey to the present one. In the human field, however, there have been numerous surveys of an equivalent condition in the newborn. Although there are difficulties and problems in comparing conditions in different species, it was hoped that contrasting the survey's findings with the huge volume of information on human neonatal retinal haemorrhages, would give some insights into the morphology and cause of equine neonatal retinal haemorrhages.

16.31 Incidence.

The incidence of retinal haemorrhages in the fundus of the Thoroughbred foals surveyed was 16% (foals) and 12% (eyes). Frauenfelder (1983) found an incidence of 10.5% (foals) and 8% (eyes) in Thoroughbred foals examined between 0 and 72 hours. The reported incidence in newborn human babies varies from 2.6% to 50% (Chase *et al*, 1950). Von Barsewisch (1979) has cast doubts on these figures, and in a huge review of all relevant papers on this subject up to 1979, stated that 33% or more of all newborn infants have perinatal retinal haemorrhages. Work since this time has roughly confirmed this: 37.3% (Levin *et al*, 1980); 41% (Egge, Lyng and Maltau, 1981); 41.5% (Van Zundert *et al*, 1986); 37.5% (Bist *et al*, 1989); 18.9% (Govind, Kumari and Lath, 1989). The huge variations in the incidence are related to the period after birth before examination takes place, the technique of examination, experience and consistency of examiner, group composition especially in relation to mode of delivery and gestational age of neonate, and perinatal/maternal history (von Barsewisch, 1979; Kaur and Taylor, 1990 and 1992). If the first day of examination is several days after birth, then the reported incidence will be lower (von Barsewisch, 1979), and Sezen (1971) proved conclusively that the earlier the baby is examined, the greater the number found with haemorrhages. This rapid decrease in haemorrhages with time reflects the small size of many of the retinal haemorrhages and the speed at which they resolve. Similarly, in this survey over half of the haemorrhages were resolving at first examination and many were quite small and in low numbers. This would have lead to a lower incidence in this survey if 90% of foals had not been examined in the first 48 hours of life, which is now the accepted limit in the human field (Kaur and Taylor, 1990). This may be one of the reasons why Koch *et al* (1978) and Latimer *et al* (1983) were unable to record any retinal haemorrhages in their surveys of slightly older foals.

The technique of examination and the experience of examiner are also important factors. Small, or 1 or 2 haemorrhages may be missed or misinterpreted by the examiner especially if they are peripherally placed or have undergone extensive resolution. Difficulties in examining the neonatal foal's fundus should not be underestimated although, because of differences in neonatal pupil size and shape in the equine, it is not necessary to dilate the pupils artificially to carry out a competant examination of the fundus. This author believes that the direct ophthalmoscope is still the best instrument to use in the equine neonate, a view not shared by von Barsewisch (1979) in the human. There is no doubt that experience of handling and examining neonatal foals, both generally and ophthalmologically, is essential in gaining as much information as possible. The patience of a saint is sometimes required by examiner and handler.

The population of child studied also has an affect on the incidence of retinal haemorrhages. No racial differences have been found (von Barsewisch, 1979) but variations in parity of mother, mode of delivery, gestational age of child, and clinical behaviour of the neonate have all been shown to have considerable affects (Baum and Bulpitt, 1970; Planten and Schaaf, 1971; Besio *et al*, 1979; von Barsewisch, 1979; Levin *et al*, 1980; Egge, Lyng and Maltau, 1981; Egel *et al*, 1988; Svenningsen and Eidal, 1988). The populations studied have not always been large enough and many studies have concentrated on special care baby units, and have not been random samples. The population studied in this survey was randomly selected from 3 different locations in two countries, with no bias towards any particular condition. There appeared to be no statistical bias to any location. The Thoroughbred horse itself is, however, a very highly selected breed and a wider survey across all breeds might well show a significant difference in incidence.

The possible connection between retinal and subconjunctival haemorrhages in NMS has been made (Rossdale and Ricketts, 1980). This survey has already proved that there is no connection between subconjunctival and retinal haemorrhages in normal or abnormal foals. Therefore, it appears most likely that retinal and scleral (subconjunctival) haemorrhages occur in some NMS foals on a purely chance basis, although there may be some similarities in pathogenesis.

16.32 Eye Distribution.

The left and right eye distribution of retinal haemorrhages in this survey was not even but, when the bilaterally affected cases were added, the difference did not appear to be significant. Frauenfelder (1983) also found a similar eye distribution. Bilateral retinal haemorrhages were more common than unilateral, especially in females and where the number of haemorrhages were large. Many of the human studies do not record eye distribution, but Lie Kay Hoo (1973) and Bist *et al* (1989) found a left/right/bilateral distribution very similar to this survey. Baum and Bulpitt (1970) also found a similar eye distibution and noted that haemorrhages were smaller and less extensive in unilateral cases, although von Barsewisch (1979) did not confirm this. Maltau and Egge (1980) did not confirm any unilateral/bilateral bias but Schenker and Gombos (1966) noticed that retinal haemorrhages were more severe on the side where a vacuum extractor was placed (see later sections). Initially, it was thought that there was a marked asymmetric distribution according to whether a left or right occipital presentation had occurred during birth, but von Barsewisch (1979) was unable to confirm this. No relationship between left/right distribution and the aetiology of retinal haemorrhages has been found in the human neonate. Whether a unilateral incidence points to asymmetric factors during birth is possible, particularly if the direct blunt trauma theory in the human (Lie Kay Hoo, 1973), and foal (Whitley, 1990), is believed. The slightly more common bilateral incidence in the human neonate is probably a reflection of the difference in head shape and eye position.

16.33 Sex Distribution.

There is a statistically significant, increased number of female foals with retinal haemorrhages in this survey. 50% more female foals were affected. Frauenfelder (1983, unpublished) found an even sex distribution, but did note that the most severe retinal haemorrhages occurred in female foals. Initial reports in human literature (Stumpf and von Sicherer (1909) quoted by von Barsewisch, 1979) found a slightly higher incidence of retinal haemorrhages in males, suggested as being a result of larger cranial circumference in the male child. More recently, other surveys have found no obvious sex distribution (Baum and Bulpitt, 1970; Levin *et al*, 1980; Bist *et al*, 1989). An increased incidence of papilloedema in female foals has already been found in this survey, and considering the close statistical relationship between retinal haemorrhages and papilloedema, this is not surprising. Whether this points to a similar aetiology will be discussed later. Frauenfelder (1983) speculated that filly foals may have lower birth weights (Rossdale and Ricketts, 1980) and, therefore, the intrauterine pressure may be concentrated and lead to increased intracranial and intravascular pressures. Overall in this study there was no relationship between sex and birth weight, but examination of the weights of the retinal haemorrhage foals does show that most of the female foals affected are in the 45-50kg group, whereas the males are in the 51-56kg and >56kg groups. It is possible, therefore, that the slightly lower than average birth weight in some female foals is a predisposing factor, while larger size, especially head circumference, may be significant in male foals.

16.34 Morphology of Retinal Haemorrhages.

During this survey the morphology, in terms of number, type, distribution and stage of development of the neonatal retinal haemorrhages was recorded for each eye, in each foal. Various classification systems have been developed in the human field in an attempt to relate haemorrhage morphology to: level of haemorrhage within the retina; degree of damage within the eye and, by inference, that elsewhere in the nervous system; the rate of resolution; the long term effects; and the possible aetiology.

a) Numbers of Haemorrhages.

54% of eyes had numbers of haemorrhages between 1 and 5, 18% between 6 and 10, and 28% had greater than 10. Over 20 haemorrhages in one eye were sometimes recorded. Involvement of both of the eyes became more likely as the number of haemorrhages in one eye increased. Several cases of retinal haemorrhages had differences between eyes in numbers, distribution pattern, and type of haemorrhages. This situation has been recorded in the newborn human (Baum and Bulpitt, 1970; von Barsewisch, 1979; Maltau and Egge, 1980; Van Zundert *et al*, 1986; Svenningsen, Lindemann and Eidal, 1988) and no explanation is known, although von Barsewisch (1979) stated that it pointed to individual anatomic variants relating to possible pathogenesis. The large percentage of foals with small numbers of haemorrhages, especially if unilateral, may mean that inexperienced veterinary surgeons might easily miss the presence of haemorrhages, particularly in an uncooperative foal. Concentration on those areas of increased distribution in the fundus (see later section) should help the chances of visualisation. Many authors have attempted to classify the severity of retinal haemorrhage in the newborn by counting numbers of haemorrhages (Kobayashi *et al*, 1964) or, more recently, counting numbers of individual types of haemorrhages (von Barsewisch, 1979; Maltau and Egge, 1980). Kobayashi *et al* (1964) used categories exactly as in this survey, but von Barsewisch (1979) related number of haemorrhages to their shape and probable location in the retina. Maltau and Egge (1980) counted numbers of haemorrhages into categories based on size.

b) Type of Haemorrhages.

The type of haemorrhages seen in the foals' fundus were split into two main groups relating to shape, with a further subdivision of one into size and shape. Approximately 38% of eyes had the small punctate type, whilst 56% had splash-like haemorrhages, these being the two main categories. 8 of the foals that had the splash-like haemorrhages were of a smaller type than average. 3 foals had a mixed pattern of small punctate and splash-like haemorrhages. There was considerable variation in type of haemorrhage between eyes in bilateral cases. In this survey, the type of haemorrhage which occurs appears to be related to the numbers found, with the punctate type usually seen in low numbers, and the splash-like especially when numbers are over 10. Similar findings were recorded in humans (von Barsewisch, 1979). He categorised haemorrhages into 5 groups based on numbers and type, with small numbers being associated with small linear haemorrhages, and larger numbers with predominently flat and/or submembranous haemorrhages. The types of haemorrhage, in this survey, do not appear to develop or change from one to another, and undergo similar patterns of resolution, both morphologically and chronologically. The increased numbers of the more diffuse splash-like haemorrhages in the resolving category is related to the pattern of resolution (see later).

Based on combined histological and fundoscopic examinations, von Barsewisch (1979) tried to relate appearance of haemorrhages with their origin and level within the retina. He divided his results into 2 groups, intraretinal and extraretinal. The former were by far the most common and included: flame-shaped haemorrhages of the nerve fibre layer, the most common and which can assume 4 different shapes depending on the orientation of the nerve fibres; granular haemorrhages of the internal granular layer, slightly less common, more uniform and circumscribed, and occasionally extending into the external granular layer as well; and hemispheric submembranacious haemorrhages, often involving the macular layer or periphery. Extraretinal haemorrhages are rare and consist of various degrees of hyaloid haemorrhage which, in the most severe forms, have retinal vessel congestion and true vitreous haemorrhage. Jayanthi and Aurora

(1978), in a rather poor report, stated that the haemorrhages were mostly situated in the inner four layers of the retina.

Egge, Lyng and Maltau (1980) graded the morphology of the haemorrhages purely on size with 4 grades ranging from grade 0 (nil) to grade 3 (fundi with haemorrhages bigger than the optic disc). The lower grades had fewer haemorrhages, in general, with larger numbers and a more mixed pattern as the grading increased. The intention of this system was to relate the degree of haemorrhage to aetiological factors such as mode of delivery and also, to indirectly assess the likelihood of brain damage. Further work by Svenningsen and colleagues has not confirmed the correlation of degree of retinal haemorrhage with increase risk of brain damage (Svenningsen *et al*, 1987). None of the haemorrhages in the foal survey were larger than grade 2 on the above described scale, and most were only grade 1. This reflects the smaller size of equine retinal haemorrhages in comparison to their human equivalent.

Kaur and Taylor (1990), recently stated that retinal haemorrhages occur when there is extravasation of blood, either into the retina itself (intraretinal), between the retina and the RPE (subretinal), or between the retina and the hyaloid face of vitreous body (subhyaloid or preretinal). They added that the shape and colour of the haemorrhages are determined by the level/s of the retina affected, and they are often mixed. They classified retinal haemorrhages into 4 groups based on morphology and location within the retina: pre-, intra- and sub-retinal, and choroidal. Kaur and Taylor (1992) stated that neonatal retinal haemorrhages are usually a mixture of splinter-shaped, flame-shaped and dot/blot (intraretinal), with rare subretinal and preretinal haemorrhages. Only the intraretinal forms have been recorded in neonatal retinal haemorrhages according to Baum and Bulpitt (1970) and these can be divided into splinter, flame, lake or geographical, and dense blob types. Severe venous congestion and possible increased tortuosity of retinal vessels commonly accompanied the more extensive haemorrhages in human babies. In this survey it has already been stated that these changes appeared more commonly in the retinal haemorrhage and/or papilloedema groups.

Although the fundus of the human and equine eye are different in anatomy and morphological appearance, and comparisons may be unproductive, it does appear that there may be some similarities between retinal haemorrhages in both species. The majority of retinal haemorrhages in the human occur in the retinal layers, either the superficial nerve fibre layer or deeper in the granular layers. Most veterinary works have suggested that they are either in the choroid (Bistner, 1984), or the subretinal space (Matthews *et al*, 1990). No histological work has been carried out in the horse, including this study (no PM material was available), and therefore the level of haemorrhage is unknown. Although the human fundus has a more extensive retinal vessel supply than the horse, the latter does have a considerable vessel pattern in the peripapillary region and, therefore, in basic retinal structure, would not be dissimilar in this area. It seems likely, therefore, that the retinal haemorrhages in this area could be intraretinal, as opposed to choroidal. In those two foals with optic disc haemorrhages the source of the bleeding must have been from retinal vessels. The splinter and small flame-shaped haemorrhages in the human appear most closely analogous to the larger, splash-like haemorrhages recorded in the foal. The small punctate type in the foal do have some similarities with the granular haemorrhages, but are by no means equivalent. The other types recorded by Baum and Bulpitt (1970), von Barsewisch (1979), and Kaur and Taylor (1990 and 1992) have no equivalent in the equine. No extraretinal lesions were recorded in the foal. It was not possible in this survey to detect any relationship between type of haemorrhage and their distribution (related to retinal/choroidal circulation). In other non-papillary areas of the fundus, because of the difference in blood supply, intraretinal lesions are perhaps unlikely. Subretinal lesions (between photoreceptors and pigment epithelium) typically in the human appear as blotchy red areas, with an elevated retina (Kaur and Taylor, 1992). On resolution they can result in retinal pigment epithelium disturbances and mechanical interference with the choriocapillaris (Kaur and Taylor, 1990). Sub-retinal pigment epithelium haemorrhages, derived from the choriocapillaris, usually lead to changes in the pigment epithelium in the human (Kaur and Taylor, 1992). None of the foals, after resolution of the haemorrhages, had any evidence of RPE changes on ophthalmoscopy and this author considers it unlikely that neonatal retinal haemorrhages occur at the subretinal level. Choroidal haemorrhagic lesions in the human often form pool-like areas which appear dark reddish-blue and resolve completely to leave a normal fundus. If the choroidal vessels are involved in the equine, it seems likely to be at the choriocapillaris level, because deeper derived haemorrhage would be hidden or modified by the presence of the tapetum. In conclusion, the level of retinal haemorrhages and their source/s within the fundus awaits a histological study.

c) Distribution in the Fundus.

All retinal haemorrhages, except 2 affecting the optic disc, were located in the tapetal fundus. It is possible that the retinal haemorrhages occurred in both tapetal and non-tapetal fundi (human retinal haemorrhages can occur in the whole fundus), but that the dense RPE pigment in the non-tapetum obscured the retinal haemorrhages from view, either physically (if derived from the choroidal circulation), or visually (if sub-retinal/retinal). The distribution and number of retinal haemorrhages were statistically related in this survey. When numbers of lesions are low (5 or less) then they occur in a discrete area, usually close and dorsal to the optic disc. As numbers increase, the distribution becomes more widespread. Ehlers *et al* (1974) described the peripapillary region as the most usual area to be affected in the human, and stated that as numbers of haemorrhages increased the more widespread the area of fundus covered. They reported, in a few cases, some peripheral haemorrhages which they described as choroidal. The previously reported difference in distribution pattern in some bilaterally affected eyes was perhaps less marked than that between eyes in numbers and type of haemorrhages.

In the human, classification according to distribution location is considered possibly the most significant. Of particular interest to the human ophthalmologist is the involvement of the macular region (von Barsewisch, 1979). Originally it was suggested that disruption of foveal receptors by macular haemorrhage in the newborn might give rise to organic amblyopia (Enoch, 1959; von Noorden, 1967). However, studies by von Noorden and Khodadoust (1973), Lowes *et al* (1976) and Egge *et al* (1980) did not confirm this suggestion. No true macular exists in the equine and, therefore, particular distribution patterns may not be so important. The long term effect of the retinal haemorrhages in this survey will be discussed later.

2 foals had retinal haemorrhages affecting the optic disc. Only single, unilateral lesions were involved in the centre of the disc. No record of optic disc haemorrhage in the human form of perinatal retinal haemorrhages can be found. The haemorrhage almost certainly came from retinal vessels in this area, possibly one of the occasional tortuous vessels seen in the centre of the disc in some foals. These haemorrhages appeared as a small splash-like form and behaved in a similiar way to other types of retinal haemorrhages.

d) Stage of Development.

14 foals in this survey had acute haemorrhages of both types. These were defined as red or reddish-purple with well defined edges. 17 foals had haemorrhages that were resolving. There was no relationship between the appearance of the haemorrhages, as regards stage of resolution, and examination time. This is not surprising since the vast majority of foals in this survey were examined within 24-48 hours of birth leaving only a short time for resolution to begin. However, 5 foals did have evidence of resolving haemorrhages when examined as early as 12 hours after birth. These foals did not appear to differ significantly from the other retinal haemorrhage foals in any parameter. A possibility might be that the retinal haemorrhages may have occurred in the foetus prior to parturition, but all the human literature from Koningsten (1881, quoted by von Barsewisch, 1979) onwards up until the present day has stated that the haemorrhages occur at birth. It seems most unlikely, therefore, that pre-partum haemorrhage did occur. A more likely scenario is that these particular foals had haemorrhages that resolved faster than average, either because of a difference in type of haemorrhage, or due to individual foal affects. Giles (1960), in a survey of neonatal children, started at 1 hour after birth, did notice rapid resolution in some individuals. The different types of haemorrhage in the human are also recorded as having very different rates of resolution (von Barsewisch, 1979).

It is also possible that some of the haemorrhages in this survey that did not appear to resolve early, were examples of postnatal extension. There are some reports of this occurring in children on quite a substantial scale (Evsyukora, 1969, and Kozuhowska, 1954, quoted by von Barsewisch, 1979) but, in general, only limited spread in the first day is recorded in occasional newborns (Baum and Bulpitt, 1970). They considered that this was due to delays in fibrin occluding the damaged vessel/s and slow penetration of the surrounding area of retina by blood cells. Many reports, as in this survey, did not record any expansion of haemorrhages after initial identification (von Barsewisch, 1979).

The rate of change, and ultimate resolution, of the retinal haemorrhages in this survey was quite variable. Examination of cases where there was a difference between eyes in type and number of haemorrhages, lead to the provisional conclusion that, in general, large numbers of haemorrhages took longer to resolve than small numbers. In addition, large splash-like haemorrhages tended to disappear more slowly than small splash or punctate haemorrhages. The position of the haemorrhage did have some affect, with the peripheral haemorrhages usually resolving first. In the human the type and position of retinal haemorrhages has a marked effect on resolution. Sezen (1971) found that flame-shaped haemorrhages had all disappeared in 5 days, and sometimes as early as 24 hours, whilst the small, round, deep haemorrhages took 14-21 days. Baum and Bulpitt (1970) also found a similar affect with splinter haemorrhages disappearing in 2-3 days, flame-shaped at 10 days with some resolving as early as 2 days, and dense blob persisting for 3 or more weeks. The latter was often associated with the macular, and other authors have noticed a very prolonged resorption time, of up to several months, for haemorrhages in this area (Neuweiler and Onwudiwe, 1967; Baum and Bulpitt, 1970; Sezen, 1971; Ehlers *et al*, 1974; von Barsewisch, 1979).

The pattern of resolution in this survey was centripetal, with the onset of resorption visible first as the margins of haemorrhage become more indistinct. This has also been reported in the human (Critchley, 1968; Baum and Bulpitt, 1970; von Barsewisch, 1979). Thus haemorrhages tended to be better defined both in shape and colour in the acute stage, being red or red-purple with sharp edges. Within 2-3 days the colour mellowed to a mauve-purple and the definition was less obvious. Their numbers and size, especially in the larger haemorrhages, would be similar to that in the acute stage although, in occasional foals with small numbers or size of haemorrhage, they had disappeared altogether. Gradually over the next 3-5 days the haemorrhages became even paler and more diffuse, and generally all the haemorrhages in this survey had started to decrease in number and size. The total disappearance of the retinal haemorrhages varied between 5 and 9 days, with none being present in any foal by 10 days of age.

16.35 Aetiology.

The actual aetiology of retinal haemorrhages in the equine neonate has not been clarified. Many workers have stated that it is part of the trauma of birth (Bistner, 1984; Lavach, 1990; Whitley, 1990). Others have considered it as part of the Neonatal Maladjustment Syndrome (NMS) (Mahaffey and Rossdale, 1957; Barnett, 1975; Rossdale and Ricketts, 1980). Great speculation on the origin of retinal hemorrhages in the human neonate has occurred since they were first discovered, and vast numbers of surveys have been carried out. As it appears that no single factor explains their presence, the various results obtained are in considerable disagreement. To evaluate the different factors involved, the neonatal and maternal parameters of the retinal haemorrhage and non-retinal haemorrhage groups of foals in this survey were compared. Results of this comparison were evaluated in the light of human work, and out of this a selection of important factors was hoped to be reached. The affect of sex on the incidence of retinal haemorrhages has already been discussed.

Neonatal Factors.

a) Foal Birth Weight.

The results of this survey suggested that foal birth weight may be a factor in the incidence of retinal haemorrhages. Overinterpretation of these results, particularly those at the ends of the spectrum, is dangerous and has tended to occur in the past in human reports (von Barsewisch, 1979). Certainly the majority of foals were within the expected bands of average birth weight for a Thoroughbred foal (45-55 kg), but of particular interest were the increased incidence of female foals of average birth weight with retinal haemorrhages. This survey has already proved that birth weight is not affected by sex. Similarly, the male foals with retinal haemorrhages are overrepresented in the higher body weight categories (see earlier).

In general, the human work has tended to dismiss the affect of sex (Baum and Bulpitt, 1970; von Barsewisch, 1979; Levin *et al*, 1980), although in those surveys where it was considered important, body weight or head circumference was thought to be a factor (Critchley, 1968; Bist *et al*, 1989).

Very obvious in this survey was the absence of retinal haemorrhages in the low body weight foals, many of which were premature or dysmature (see later section). Although most of the human workers who consider birth weight immaterial, have also stated that gestational or clinical signs of prematurity have no affect on incidence of haemorrhages, others have found a significant decreased incidence in pre-term neonates with low birth weights (Maltau *et al*, 1984; Egel *et al*, 1988; Fledelius, 1990).

Several workers in the human field have stressed the importance of head size (cranial circumference) on the incidence of retinal haemorrhages (Maltau *et al*, 1984; Bist *et al*, 1989) rather than body weight. Baum and Bulpitt (1970) and von Barsewisch (1979) have found no correlation of cranial circumference with haemorrhage incidence. Bist *et al* (1989) did think that head circumference was related to sex and that its importance was in the increase it would lead to in cephalo-pelvic mismatch, and hence increase in head pressure and retinal haemorrhages. Although no foal head circumferences were measured in this survey, it may be that the increased incidence of males in the larger body weight categories is a reflection of larger head size and not just body size.

b) Foal Colour.

The incidence of retinal haemorrhages was not affected by foal colour in this survey. In man there has been no evidence to suggest that race or colour predisposes to retinal haemorrhages (von Barsewisch, 1979).

c) Foal Behaviour.

There was no significant difference in the incidence of retinal haemorrhage in relation to foal behaviour or time to stand and suck, in this survey. Premature/dysmature foals were underrepresented in the retinal haemorrhage group. Interest, in the human field, in the relationship of retinal haemorrhages in the immature neonate, was based on their possible relationship with intracranial haemorrhage. Initially, early workers thought that there was a higher incidence (Sezen, 1971; Sykes, 1931, quoted in von Barsewisch, 1979) but more recent publications, like this survey, have reported a lower incidence, and in some a reduced severity (von Barsewisch, 1979; Maltau, Egge and Moe, 1984; Egel, Chander and Rathi, 1988; Egel *et al*, 1988; Govind *et al*, 1989; Fledelius, 1990). Others have reported no affect on incidence by gestational age (Levin *et al*, 1980; Svenningsen and Eidal, 1987; Bist *et al*, 1989). Egel, Chandler and Rathi (1988) further demonstrated no relationship between intraventricular haemorrhage and retinal haemorrhage in the pre-term infant. In the human neonate, other retinopathies of prematurity must also be distinguished from perinatal retinal haemorrhages and have probably caused confusion in the past (Mushin, 1971; Skalina *et al*, 1983; Fledelius, 1990). Von Barsewisch (1979) considered that 2 different factors influenced the incidence of haemorrhage in immature infants. The smaller cranial circumference, related to reduced birth weight, might reduce the trauma of delivery, whilst retinal vessel immaturity could lead to greater vulnerability. Maltau *et al* (1984) considered the lower incidence in the pre-term infant to be evidence in support of the hypothesis of foetal head compression with consequent venous congestion as the main cause of retinal haemorrhage.

In this survey, premature/dysmature foals were lower in birth weight than normal foals and, although cranial circumference was not measured, it seems reasonable to suggest that their heads, and possibly chests, may have been smaller.

Asphyxia, often evaluated by the Apgar score, has often been suggested as another factor in the incidence of retinal haemorrhages in the newborn baby (Bergen and Margolis, 1976; von Barsewisch, 1979). More recent studies have found no such correlation (Ehlers *et al*, 1974; Levin *et al*, 1980; Maltau, Egge and Moe, 1984; Govind *et al*, 1989). Svenningsen and Eidal (1987) went into more detail in investigating asphyxia and found no correlation between umbilical artery pH and Apgar score (reflecting the lack of sensitivity of Apgar scoring in assessing asphyxia), and also between retinal haemorrhages and Apgar score or umbilical artery pH. Von Barsewisch (1979) and Bist *et al* (1989) both felt that asphyxia, although not a direct factor, might predispose to retinal haemorrhage by causing hypoxia-induced vasodilation and vascular fragility.

The incidence of asphyxia during the birth process in the foals in this survey was difficult to assess based on the foaling history and clinical neonatal examination carried out. No obvious cases were detected but this probably reflects the similiar lack of sensitivity of the examinations performed in this survey and those in humans using Apgar scoring. The foal which is perhaps the most interesting in this area of the discussion, is the NMS foal. Many workers have suggested that the lesions within the brain of these affected foals, and those with significant vascular accidents (SVA), are caused by hypoxia. This leads to ischaemic necrosis of vessels and CNS parenchyma (Rossdale and Ricketts, 1980; Mayhew, 1982 & 1988). The possibility of similar hypoxic pathways in the pathogenesis of both conditions may have lead to the original idea that retinal haemorrhages were connected with the NMS syndrome.

Other causes of retinal haemorrhages in the human neonate have included haemorrhagic disease of the newborn (von Barsewisch, 1979). However, Baum and Bulpitt (1970) found no difference in incidence of retinal haemorrhages in relation to blood haematological analysis and clotting times/factors. None of the foals in this survey with retinal haemorrhages had any abnormalities of clotting times or routine haematology results.

16.36 Aetiology

Maternal Factors.

a) Parturition.

In this survey there was a significant association between foaling category and incidence of retinal haemorrhages, particularly with those types of foalings classified as miscellaneous. 2 of the group were prolonged first stage parturition, 3 were second stage problems including delay in passage through the pelvic canal and early separation of the placental supply, and 1 was a third stage abnormality. One foaling was unattended and probably normal, and the other was an obturator paralysis in the mare caused by relative foetal oversize and hip lock. The category 5 foaling was also a prolonged second stage due to manipulations for a postural dystocia. There was a slightly increased number in category 3, foetal oversize, which also tends to increase the length of second stage parturition. Frauenfelder (1983 unpublished) also found an association between foetal oversize/manipulations at birth and retinal haemorrhages. Also, as in this survey, he noted this association in the foals with papilloedema.

In the human field, there is no doubt that different types of delivery have a definite influence on incidence and intensity of retinal haemorrhages (von Barsewisch, 1979). Vaginal delivery is associated with a higher incidence of retinal haemorrhages than Caesarean section (Neuweiler and Onwudiwe, 1967; Besio *et al*, 1979; Levin *et al*, 1980; Govind *et al*, 1989). Where they do occur, they seem to be more related to the attempts at delivery or onset of asphyxia prior to the Caesarean. One explanation for the difference in incidence is that the compressive effect on the cranium is much less in the Caesarean born neonate. None of the foals in this survey were born by Caesarean section and the incidence in these foals has not been studied

The presentation of the cranium asymmetrically in relation to the maternal pelvis was originally suggested as a cause of unilateral haemorrhages in the newborn human, but later work did not establish this (von Barsewisch, 1979). Although no specific record of the symmetry of parturition was made in this survey, it is unlikely that the foal can be born through the pelvis and vulva unless it is symmetrically presented. It is considered unlikely that this factor has a significant affect on retinal haemorrhage incidence in the foal. Breech presentation is associated with fewer haemorrhages in the human neonate (Planten and Schaaf, 1971). This is thought to be due to different compression affects on the head and haemodynamic conditions as it is delivered last. Again haemorrhages are only seen if other obstetric complications are present as well.

Obstetric procedures used in human medicine to assist in delivery of the baby and shorten a prolonged second stage of labour are forceps delivery and vacuum extraction. An increased incidence of retinal haemorrhages is generally seen after the use of both types of artificial delivery, although much controversy surrounds the subject (Besio *et al*, 1979; von Barsewisch, 1979). More recent studies have split into 2 camps, with one group suggesting that vacuum extraction increases the incidence by 1½-2 times (Ehlers *et al*, 1974; Egge, Lyng and Maltau, 1980 & 1981; Levin *et al*, 1980; Van Zundert *et al*, 1986) whilst others found it did not (Svenningsen *et al*, 1987; Svenningsen and Eidal, 1988). All are now agreed that forceps delivery probably has a lower level of incidence than spontaneous vaginal delivery. This is possibly due to the protective effect of the forceps on the cranium preventing rapid decompression (Levin *et al*, 1980), or because of the reasons for use of the forceps i.e. hypoxia and the need for a rapid birth, effectively shortening the duration of second stage labour (Egge *et al*, 1980 and 1981). Von Barsewisch (1979) summed-up the situation best when he stated that it was not the procedure itself but the condition necessitating its use that is responsible for the higher incidence of haemorrhage. The most usual reason in the human is prolonged second stage. Although neither of these procedures is used in the foaling mare, it is the last statement which perhaps highlights the importance of the type of foaling on the incidence of retinal haemorrhages, and particulary the effect of prolongation of the second stage of parturition. Although Svenningsen *et al*, (1988) do not consider foetal head compression affects to be relevant, many workers in the human field and myself included, feel that these may also be important.

The use of oxytocin or prostaglandins has been associated with an increased risk of retinal haemorrhages (von Barsewisch, 1979), probably because of the reasons for their use, rather than the drugs themselves. However, Schoenfeld *et al* (1985) considered that accumulation of prostaglandins in the foetal circulation during induction was directly responsible for the haemorrhages, and not related to the degree or length of contractions and labour. This has not been confirmed yet by other workers and does seem rather unlikely either in the newborn baby or foal. None of the foals in this survey were induced.

b) Gestational History.

There was no statistical relationship in this survey between the incidence of retinal haemorrhages and gestational problems. A similar situation has been reported in the human (Levin *et al*, 1980). All the abnormalities detected in the retinal haemorrhage foals were related to gestational length. The 2 foals with premature dates were, in fact, physically and haematologically mature. The variation of gestational length has already been discussed and many of the differences are probably related to individual variation.

c) Parity.

No statistical relationship was detected in this survey between maternal parity and retinal haemorrhages. In the human literature there is some work to suggest that maternal parity has an affect on retinal haemorrhage incidence. The incidence increases as the parity increases (Schenker and Gombos, 1966; Neuweiler and Onwudiwe, 1967; Bergen and Margolis, 1976; von Barsewisch, 1979; Van Zundert *et al*, 1986). However, others disagree (Baum and Bulpitt, 1970; Levin *et al*, 1980; Egge *et al*, 1980 & 1981). The higher incidence of retinal haemorrhage in children from primiparous mothers has been attributed to increased rigidity of the pelvic canal and the prolonged second stage labour common in these mothers.

In this survey there certainly was a suggestion of an increased incidence of retinal haemorrhages with prolonged second stage of parturition, but this was not related to parity. Both uni- and multi-parous mares have rapid vigorous second stages to their parturition with no recorded differences in speed or length.

16.37 Long Term Ophthalmoscopic and Neurological Effects.

Retinal haemorrhage in the newborn child has been suggested as an indicator of subclinical, or minimal, brain damage or bleeding (Critchley, 1968; Egge *et al*, 1981; Maltau, Egge and Moe, 1982). However, Levin *et al* (1980) and Svenningsen *et al* (1988) disagreed with this, and Skalpe *et al* (1982) proved using CCT that there was no relationship of intracranial bleeding with retinal haemorrhages. A number of studies have confirmed the earlier findings of Bonamour (1949) that retinal haemorrhages do not produce an abnormal ophthalmoscopic appearance in later life or a long term affect on vision (von Noorden and Khodadoust, 1973; Levin *et al*, 1980). Even those haemorrhages affecting the macula appear to have no permanent affect (Lowes *et al*, 1976).

The subjective observations of veterinary surgeons in the past, that foals with retinal haemorrhages suffer no long term ophthalmoscopic, visual or neurological effects (Bistner, 1984; Munroe and Barnett, 1984; Matthews *et al*, 1990), can be confirmed by this study, since no foals showed any abnormality related to these lesions on later examinations. This statement is made within the limits of the examination that was possible.

16.38 Relationship With Other Ophthalmic Parameters.

There was no statistical relationship between the presence of retinal haemorrhages and presence of vision, ocular reflexes, scleral (subconjunctival) haemorrhages, resting pupillary size and shape, presence of hyaloid apparatus and fundic pattern. There was a statistical relationship between red-pink optic disc colour and homogenous disc character, as well as papilloedema. Although not statistically significant, there was an increased incidence of increased tortuosity and size of retinal vessels. All of these changes in the peripapillary area have been recorded in the section on papilloedema, and are interrelated. This relationship of papilloedema and retinal haemorrhages, in the human, has been recorded by von Barsewisch (1979) and centres around the common pathway of increased intracranial pressure. This elevated pressure may affect the dural sheaths of the optic nerve (leading to papilloedema) which, when they reach a CSF pressure level or greater than that of systemic arterial blood pressure, obstruct venous outflow from the central retinal vein and cause venous engorgement/optic disc colour changes and retinal haemorrhages.

16.39 Pathogenesis of Retinal Haemorrhages in the Equine Neonate.

The exact pathogenesis of retinal haemorrhages in the human neonate has been the subject of intense scrutiny since they were discovered over 100 years ago. A list of the main ideas is given on the following pages.

a) Elevation of Intracranial Pressure.

The affect of intracranial pressure and its relationship with the affect of birth on retinal circulation is discussed by Giles (1960), Schenker and Gambos (1966), von Barsewisch (1979) and Kaur and Taylor (1992). The raised intracranial and, hence, optic nerve sheath pressure is thought to compress the central retinal vein and chorioretinal anastomosis, thus raising intraocular venous pressure.

Foetal head compression leading to increased intracranial venous congestion and pressure has been suggested by Besio *et al* (1979), Levin *et al* (1980), and Maltau, Egge and Moe (1984). Svenningsen, Lindemann and Eidal (1988) found no difference in foetal head compression pressure (FHCP) between non-retinal haemorrhage and retinal haemorrhage babies, but did consider duration of increased FHCP to be important.

Thoracic compression leading to increased retinal venous pressure was considered important by Ehlers *et al* (1974) and Goetting and Sowa (1990).

b) Vascular Factors.

Conditions leading to increased foetal vessel fragility include prematurity, drugs, acidosis/hypoxia, and prostaglandins (Schoenfeld *et al*, 1985; Kaur and Taylor, 1990). Coagulopathies, anaemia, and pancytopaenia are other haematological factors that have been suggested, and it is also thought that the vascular system of young children may be particularly susceptible to abrupt changes in pressure (Kaur and Taylor, 1992).

c) Anoxia/Hypoxia.

Acidosis/Hypoxia may lead to retinal haemorrhages by causing vascular dilation, increased permeability and fragility of vessels, ischaemic necrosis and tissue injury (von Barsewisch, 1979).

d) Anatomic Conditions.

The special anatomic conditions of retinal circulation and drainage in the human, and their relationship with papilloedema/retinal haemorrhage have been proposed by von Barsewisch (1979).

e) Trauma.

Direct trauma to the eye caused by obstetrical conditions or interference was a popular hypothesis in early publications, and more recently found favour with Lie Kay Hoo (1973).

It is obvious from the foregoing list that no single factor is known to cause perinatal retinal haemorrhages. As a basis for discussion, it is worth repeating in a simplified and precise form the basic clinical facts found in this survey in connection with retinal haemorrhage.

1) The haemorrhages occur during parturition, are transient and rapidly reabsorbed.

2) They may be caused by rhexis of retinal capillaries or choriocapillaris.

3) Their greatest similarities to human haemorrhages is in those seen resulting from venous outflow obstructions such as central venous occlusion or venous obstruction in intracranial pressure elevation.

4) No correlation exists with the other perinatal ocular haemorrhage (subconjunctival) or other ocular pathology, except papilloedema.

5) Coagulopathies were not detected.

6) The incidence in foals was 16% (spontaneous vaginal delivery).

7) It is more common in females, especially in those of average body weight, and in males, where ıt occurs, birth weight is above average.

8) It is uncommon in premature/dysmature foals and those of low body weight.

9) It is related to those foaling categories with prolonged second stage and/or increased compression on head/thorax. It is not related to parity or gestational abnormalities.

10) There are no long term ocular or neurological effects, and no connection with abnormal foal behaviour.

Hypothesis.

The most popular hypothesis for the pathogenesis of human retinal haemorrhages is that involving increases in intracranial pressure due to foetal head compression (von Barsewisch, 1979; Levin *et al*, 1980; Maltau*et al*, 1984). The role of anoxia/asphyxia is slightly more controversial (von Barsewisch, 1979; Svenningsen *et al*, 1988). It is believed that severe head compression can increase intracranial and, therefore, via venous congestion, intravascular (venous) pressures (Wise, Dollery and Henkind, 1971). A long build-up of pressure caused by a prolonged second stage labour, possibly followed by a sudden decompression, is also thought to be a factor (Maltau *et al*, 1984). Svenningsen *et al* (1988) measured foetal head compression pressure (FHCP) during human labour and found no difference between levels of FHCP in non-haemorrhage and retinal haemorrhage babies in spontaneous or assisted deliveries. However, they further postulated that long periods of increased FHCP, as might occur in foetal/maternal mismatch (oversize) or prolonged second stage and dystocias, could overcome the natural tolerance of the foetal skull to compression forces and lead to increased intracranial pressures. The increase in intracranial pressure leads to a decrease in venous outflow from the cranium, venous congestion and an increase in intravenous pressures.

Rossdale and Ricketts (1980) suggested that compression of the head of the foal during parturition may increase intracranial pressure and subsequently, intravenous pressures. Rossdale *et al* (1976) recorded raised foetal blood pressures during normal delivery (peak pressures of 60-200 mmHg in jugular and digital veins). Similarly, carotid arterial pressures were measured in the same work and found to be 175/100 mmHg during delivery, falling to 100/50 mmHg at completion of delivery. If these figures are compared to that of a normal neonatal 12 hour-old foal (jugular venous pressure 5 mmHg, systemic arterial pressure 70/50-130/100 mmHg), then it can be concluded that the foetus during parturition is hypertensive.

Some of the hypertension in the parturient foal is likely to be caused by thoracic compression during passage through the maternal pelvis (Johnson and Rossdale, 1975; Rossdale *et al*, 1976). A similar pathway has been postulated in man (Ehlers *et al*, 1974; Goetting and Sowa, 1990; Kaur and Taylor, 1992). Chest compression, especially when the glottis is completely or partially closed, will increase intrathoracic pressure. This is transmitted to all vascular structures including the right atrium, leading to increased central venous pressures. This is transmitted to the head and neck veins, because of poor protection by thoracic inlet venous valves. This leads to the very high peak pressures recorded in the jugular vein of the foal as it's head emerges from the vagina (Johnson and Rossdale, 1975; Rossdale *et al*, 1976). This is often noted by those present as a more purple hue to visible mucous membranes and engorgement of the jugular vein. This subsides and reverts to a more normal appearance within 5 minutes of a normal birth (Rossdale and Ricketts, 1980). These high levels of intravenous pressure may be pulsatile due to periods of relaxation in expulsive forces during delivery, but lead to increases in the intracranial pressure and to a rise in intraocular retinal venous pressure.

The high intravenous pressures in the head and neck are added to by further increases in intracranial pressure derived from the increased intrathoracic pressure. These are transmitted via the thoracic cerebrospinal fluid and the paravertebral venous plexus (Goetting and Sowa, 1990). Further affects may be due to the high pulmonary vascular resistance in the neonatal foal (Rose and Stewart, 1983) and the high venous pressures seen in foals with seizures. The latter may be a factor in the incidence of retinal haemorrhages in NMS.

In the foal, the level of intracranial and intravenous pressure rises may be affected by the force of maternal uterine contractions, length of second stage labour, disparity of foeto-maternal size, excessive traction on limbs increasing pressure on the skull, cranium circumference, and chest size. Frauenfelder (1983 unpubl.) postulated that increased severity of retinal haemorrhages in female foals might be related to smaller sizes leading to increased force of maternal contractions and rises in intracranial/intrathoracic pressures. Certainly, in this survey, more female foals were affected and the majority of them were of an average size. However, if this theory was correct, the incidence in small foals would be high, the opposite in both human surveys and this foal survey. Other factors must also be at work. Both from the human studies and this survey there is evidence that conditions prolonging parturition, especially during second stage labour, do increase the incidence of retinal haemorrhages. Foeto-maternal mismatch, prolonged obstetrical manipulations, and stitched vulvas preventing delivery are all good examples in this survey. Disparity in foeto-maternal size may not only prolong second stage but also increase intrathoracic and intracranial pressures directly. This may be a factor in the higher incidence of retinal haemorrhages in large male foals. These foals, and some foals with large skeletal size but average body weight, will receive additional thoracic and cranial compression. This is compounded by the inevitable delays in second stage, and by the possible human interference of traction. The latter is well recognised in the human field as an additional factor in increased retinal haemorrhage incidence (Egge *et al*, 1980). Chest/skull compliance (Koterba, 1990a) may also be a factor in the incidence of retinal haemorrhage in the foal, especially those that are premature/dysmature. In these foals the chest/skull wall may be more compressible than normal and less likely to generate large increases in pressure. In normal foals the skeleton will be more resistant to compression (less deformable) leading to greater pressures and possibly, if these exceed the strength of the structure, bruising or fracture. These are regularly seen in neonatal foals, and were originally described in some cases of NMS.

Increased intracranial pressure will lead to elevated cerebrospinal fluid pressure which will be transmitted to the sheaths of the optic nerve. The increased intravascular pressures within the cranium, already described, via the increased intracranial/intrathoracic compression, may lead to cerebral oedema. The increased CSF pressure on the optic nerve within the dural space and the cerebral oedema will be reflected in the optic nerve as papilloedema. This may explain the connection between the two entities within this survey. Similar findings have been observed in man (von Barsewisch, 1979) with the incidence seen reflecting the severity of the initiating factors, and the length of time in which they can act. Papilloedema takes considerably longer to form compared to the short time in which the retinal haemorrhages can occur.

It is thought that the elevated intravascular pressure and venous drainage obstruction postulated in the human neonate is particularly relevant to the central retinal veins because of the special anatomy of this vessel in the human (Goetting and Sowa, 1990). It drains into the cavernous sinus, itself exposed to increased intracranial pressures, and there are no other significant anastomotic venous routes. In addition, CSF pressure elevation, as previously described, further compresses the vessel and occludes the only major anastomoses, the retinochoroidal circulation. The result is engorgement and venous ruptures of the retinal vessels, with extravasation until pressure conditions change and coagulation occludes the defects. In the horse the arterial and venous supply to the retina is somewhat different (Sisson and Grossman, 1975). The arteries of the retina are derived from the central retinal artery, and anastomotic branches from the short posterior ciliary arteries. Both these are branches of the external ophthalmic and anastomosing internal ophthalmic arteries. The central artery enters the optic nerve a short distance behind the eyeball and runs in the axis of the nerve. It divides 2-3mm before reaching the papilla and gives off 30-60 branches. The retinal veins accompany the arteries on their way out of the eye. Although this survey has not proved that retinal vessel damage is a source of retinal haemorrhage in the equine neonate, if this is the case, then the passage of veins through the first part of the optic nerve as it leaves the eyeball may be where compression could take place. These retinal veins drain into the posterior ciliary vein which joins the ophthalmic vein near the apex of the orbit, from where blood is then drained intracranially by the orbital vein and extracranially by the internal maxillary vein (Samuelson, 1991). Although there is more chance of variation in the drainage than in the human, both pathways could be affected by increased intracranial and intravascular pressure leading to venous congestion. Just as in the human, this survey confirmed the relationship of retinal vessel congestion and increased tortuosity with retinal haemorrhages, papilloedema and hypertension (von Barsewisch, 1979; Skalina *et al*, 1983; Kaur and Taylor, 1990).

The source of retinal haemorrhages in the foal may, however, be choroidal from the choriocapillaris. This receives its supply from the short posterior ciliary artery which perforates the sclera around the posterior pole and away from the optic nerve. The venous pathway is by 4-5 venous trunks, the vorticose veins, which perforate the sclera around about the equator and join the veins of the ocular muscles. Thence it follows a similar pathway as that described for the retinal vessels. Although the fine vascular structure of the choriocapillaris could be affected by the same raised intravascular pressures, it is possible that other factors may have an additional effect. It has been suggested that the choroid circulation is predisposed to hypertensive damage.

Von Barsewisch (1979) considers that anoxia/asphyxia is an important concurrent factor in the aetiology of retinal haemorrhages in the human neonate. Bergen and Margolis (1976) termed it asphyxic diapedesis. The vasodilation and increased fragility of the vessels caused by asphyxic episodes during foaling could predispose some foals to retinal haemorrhages. Newborn foals suffer a degree of asphyxia at birth (Rossdale, 1968 and 1970; Rose, Rossdale and Leadon, 1982; Stewart, Rose and Barko, 1984). This is often associated with increased blood $PaCO_2$, decreased PaO_2 and metabolic acidosis. Rossdale and Ricketts (1980) suggested that this might be due to: umbilical cord compression as it is dragged through the canal; lowering of placental efficiency during uterine contractions; uneven distribution of placental and uterine blood flows; or placental separation from the endometrium. An example of the latter was seen in a retinal haemorrhage foal in this survey. Premature severence of the cord immediately the foal is delivered and before respiratory rhythm is established, may cause maladaptation in the newborn foal with a profound metabolic acidosis and blood loss (Rossdale and Ricketts, 1980; Rose and Stewart, 1983). The acidosis potentiates the hypoxic effects on the blood vessels. An example of early separation of the cord due to a standing delivery was seen in this survey. Acidosis also leads to peripheral vascular resistance, decrease in cardiac output, profound changes in cerebral blood flow and ischaemia (Rossdale and Ricketts, 1980). Cerebral oedema, haemorrhage and/or ischaemic necrosis may follow. This is a sequence of events which has been observed at autopsy in foals that have suffered from NMS (Palmer and Rossdale, 1975 and 1976) and SVA (Mayhew, 1982). This may explain why some NMS foals have retinal haemorrhages and were initially recorded as part of the same syndrome. It appears likely that asphyxia at birth is a contributing factor to retinal haemorrhages in the foal, and which may influence their incidence.

Important other factors could include individual anatomic variations in blood supply and vascular fragility. Low grade coagulopathies may be a factor affecting the size of haemorrhages by preventing early formation of fibrin thrombi.

The conclusion of this hypothesis on retinal haemorrhages in the foal is that the pathogenesis is complicated, interrelated and multiple with various factors of greater or lesser importance in individual animals. It does appear, however, that intracranial and intravascular pressure affects, alongside anoxia/asphyxia and individual anatomic factors, are the major pathogenic pathways.

Finally, it should be emphasised what an astonishing phenomenon perinatal retinal haemorrhage is in the foal. The physiological process of birth causes spectacular alterations of vessel rupture and haemorrhage in the retina, a structure of great complexity and delicacy. It appears to cause no short or long term effects, resolution is quick and complete, and the observer is left wondering as to its aetiology and pathogenesis.

CHAPTER 17

CONCLUSION.

This clinical and morphological survey of randomly selected Thoroughbred neonatal foals' eyes is thought to be the first of its kind. When first instituted it had certain well-defined goals. Initially, it was hoped that the normal appearance of the neonatal Thoroughbred foal's eye could be defined and the specific differences from the adult eye highlighted. The adaptation process from neonate to adult horse has been documented for many systems and structures but not for the eye, and redressment of this imbalance was a further aim of this study. The incidence of congenital abnormalities and anomalies of the equine eye is partially documented in the literature but confusion exists in definitions and criteria, with an overuse of material referred to specialist centres. Little work has been carried out on general populations of neonatal foals to clarify the true position. This survey attempted to tilt the balance of information back towards the situation in the field. Neonatal retinal and scleral haemorrhages have fascinated human medical workers for nearly a century and some of this interest was stimulated in the author when initially confronted by the equivalent conditions in the equine neonate. The final goal of this survey, and possibly the driving force behind it, was to conduct the first study of these conditions in the equine and, hopefully, define their morphology, incidence, long term effects and possible aetiology.

The vehicle for attainment of the set goals was a detailed ophthalmoscopic examination of 169 randomly selected neonatal Thoroughbred foals in 2 areas of the U.K. and the Waikato area of New Zealand. Comparison of populations was undertaken and highlighted some differences, many of which appeared related to management practices. Previous foal surveys have had rather loose definitions of candidates and, therefore, in this study only foals less than 96 hours of age (neonates) were used. Foals were not selected in any other way and all were examined without the use of chemical restraint or ophthalmic drugs, so that normality was not modified. The lack of certain specialist equipment did affect the detail in one or two small areas (i.e. slit-light biomicroscope in lens opacities) but, in general, the vast majority of information required was easily obtained with basic ophthalmological instrumentation equally available to the practising clinician in the field. Much of that recorded in this study is there for the veterinary surgeon to see for him/her self on a daily basis.

An important part of this survey, and not undertaken in any previous study of the foal's eye, is the detailed clinical examination of the foal and mare both pre- and post-partum. The purpose of this information was: to generate a database for each foal so that individuals could be identified and traced, if required, in later life; to assess the gestational and parturient factors that may affect the neonatal foal and its development, both generally and more specifically its eye; and to identify foal disease processes that may directly or indirectly contribute to variations in the morphology of the neonatal foal's eye.

The data from the general and ophthalmic examinations was subjected to a detailed statistical analysis to record the incidence of variables and to pinpoint any relationships between them. The large number of variables within each foal examination and the relatively small numbers, statistically, of foals examined did require the interpretation of the results to be very careful and at times with scepticism. A strict 1% significance level was used at all times. Those variables with small numbers of foals were often deleted from calculations or special techniques were used. Although these can be highly acccurate in their predictions, a further continuation of the study with larger numbers of foals would give a clearer picture of the incidence and significance of the less common anomalies and abnormalities.

There was a strong statistical relationship between mare, stallion and foal coat colour which suggested a high heritability of this trait in the Thoroughbred. Over 60% of parents and progeny had a bay coat colour and 25% were chestnut. As it was later proven in this survey that coat colour had a significant affect on pigmentation of many areas of the eye, this relative homogenity of coat colour had a profound influence on the incidence of certain parameters. The inclusion of other breeds into the survey might have lead to different conclusions.

The incidence of abnormal gestational history at 28% initially appeared high, but careful scrutiny revealed the majority (85%) were related to gestational length variations. It was concluded that rarely did these gestational length variations have any affect on the foal that was produced, or the parturition difficulty. It was considered that the majority of these variations were within the normal biological range for the Thoroughbred mare. A number of other parameters such as premature lactation also fell into the grey area of variation within biological normality and, despite being classified as having an abnormal gestational history, such mares produced clinically normal foals. Nevertheless, abnormal pregnancies had an affect on the foaling category and, if the biological variants were removed, on the incidence of abnormal foal behaviour and abnormalities of the eye. Maternal parity was related to foal size and type of foaling, with uniparous mares producing smaller foals with, perversely, a higher number of relative foetal oversize foalings.

The incidence of dystocias in this survey was lower than expected (2%), but that of foetal oversize was higher (16%). Foaling category was statistically related to the parity and gestational history of the mare, and with foal behaviour and size. It is the latter relationship that is of most interest when looking at the affect of foaling on the neonatal eye.

The pattern of foaling times in this survey very closely resembled that for the Thoroughbred mare already stated in the literature with 78% of all foalings occurring within the period of 20.00-04.00 hours, with obvious consequences on stud personnel and veterinary surgeons' sleep patterns.

90% of foals were examined by the end of their second day of life which is in marked contrast to the four previously published eye surveys in foals. All 169 foals were examined within 96 hours and comparison of the ophthalmic findings at various examination times allowed a picture of the changing physiological baseline of the eye to be built up. Male foals appeared to have longer gestation periods but there was no significant relationship between foal sex and birth weight or foal behaviour. 89% of foals in this survey had a birth weight between 45 and 55 kgs with New Zealand foals being larger. Low birth weight and abnormal foal behaviour were strongly related, many of them being classified as dysmature foals. Foal size and abnormal gestational history were not related but birth weight and category 3 foalings were. 13% of foals in this survey were classified as abnormal.

No work exists as to the incidence of foal diseases in the general population of foals, although data derived from neonatal intensive care units is abundant. There was a higher incidence of neonatal disease in New Zealand foals probably related to poorer care and supervision of foals. Individual incidences of neonatal disease was interesting in this survey because it appeared to differ in some cases quite markedly from the limited information already available on the subject. Group I or septicaemic conditions were uncommon whereas Group II, and especially dysmature foals, were common. Differences in populations, standards of neonatal care, prophylactic drugs and monitoring of immunological status may have been factors in the overall picture of foal diseases in this survey. All Group III or developmental disorders were various forms of congenital flexor deformities whose significance lay in the fact that they prolonged the time to stand and suck.

The times to stand and suck for foals in this survey were broadly in line with previous work with 89% standing without assistance within 1 hour and 76% nursing from the mare in less than 2 hours. Times to stand and suck were not related to foal sex or birth weight, but were to foal behaviour, with times being significantly increased in abnormal foals. On the evidence of this survey, useful parameters for stud personnel to monitor on a stud farm include gestational age of foals, body and placental weight, time to stand and suck, and body temperature.

All the foals in this survey had eyes open at birth, with 98% of foals having normal vision at the time of first examination. The most effective means of testing vision in the neonate as determined by this survey was close observation of the foal when loose, both in a foaling box, nursery paddock, or moving between the two. Experience in understanding neonatal behaviour was found to be vital in assessing responses. Maze tests, with the foal at liberty in an area where a number of innocuous objects were placed, were also useful. The menace reflex was absent in 96.5% of foals and appears to be of little use in neuro-ophthalmological testing in neonatal foals. The 3 blind foals in this survey all had multiple and severe systemic problems and 2 of these also had severe uveitis.

The menace reflex was absent in 96.5% of foals at first examination. Menace response and examination time were correlated with older foals being more likely to have a positive reflex. It is likely that the menace response develops in the first 2 weeks of life although serial examinations on a daily basis during this period would be required to confirm this. 96% of foals had a pupillary light reflex, 80% of which had a slow or sluggish response. Older foals tended to have a more rapid response. Consensual and direct reflexes were similar, although a marginal difference in the contralateral pupil in the consensual group did exist. It was not possible to confirm that PLR in the neonatal foal is a useful part of a neurological examination, particularly in localising lesions. The blink and photomotor reflexes appeared in this survey to give little useful information in assessing neuro-ophthalmological function in neonatal foals as all foals were positive.

All foals in this survey had two eyes with normal sized globes and orbits at first examination. A slight ventro-medial deviation was noted in all foals in both eyes at the first examination. The incidence of congenital disease of the orbit and globe, including microphthalmia, was very low, although a true picture would require a substantially larger survey.

In this survey, the size, shape and appearance of the eyelids and palpebral fissure were similar to previous descriptions in the foal, with little difference between neonate and adult in this area. The normal appearance of the cilia is long and dense in the upper eyelid and short, rather sparse in the lower eyelid. The normal pattern of the vibrissae was long and between 1 and 5 in the upper eyelid, and long and between 6 and 10 in the lower eyelid. 5% of foals had eyelid abnormalities, the majority of which were entropion. This is a higher incidence than previously recorded and may be related to the populations, age and breed examined. 5 of the 6 foals with entropion had the secondary form as a complication of systemic disease and this casts doubt on the hereditary theory of the problem in the Thoroughbred. Only lower lids were affected. 3 foals had increased lower lid skin folds (orbital sulci), a condition not previously reported. They were not associated with ocular abbnormalities and may be a normal variation in early neonatal changes in skin pliancy, body fluid balance and muscle tone.

The appearance of the conjunctiva in the neonatal foal does not differ significantly from that seen in the older foal and adult horse according to the results of this survey. Conjunctival pigmentation differences between foals partially correlated with coat and nictitans colour, with chestnut foals having less or no bulbar conjunctival pigment and whole-coloured pink nictitans. Congenital abnormalities of the conjunctiva did not occur but acquired abnormalities were found in 11% of foals. 5% of foals had conjunctivitis which is a higher incidence than that reported in previous older foal surveys. Most of the cases of conjunctivitis were primary and due either to entropion irritation or direct trauma. In general, conjunctival abnormalities were related to lid or nictitans problems and reflect their interdependancy.

The membrana nictitans was normal in size and shape in all foals in this survey, except one right eye, with pigmentation of the leading margin in 74% of foals. This was related to bay and grey coat colour. Non-pigmented margins were found in 25% of foals almost all of which were chestnuts. Pigmentation of the nictitans was invariably bilaterally symmetrical and related to bulbar conjunctival pigmentation.

The normal cornea in this survey was clear, oval and broader nasally, which has been recorded in previous older foal studies. The scleral shelf or overhang was recorded in over two-thirds of foals, with the majority exhibiting this in the dorsal and ventral aspects of the eye. The presence of this shelf diminished the view of the iridocorneal filtration angle and pectinate ligaments in these areas. Insertion of these pectinate ligaments into the cornea at the termination of Descemet's membrane was commonly recorded. In all but one of the recorded cases, they were seen on the temporal and nasal aspects of the eye as a white or grey-blue line. The large number of foals with these "grey lines" and the lack of a relationship with any ocular abnormality in this survey lead to the conclusion that they are a common normal finding in foals, just as other authors have suggested they may be in adults. The relationship of pectinate or grey lines in this survey with iris colour and appearance, independent of coat or conjunctival colouring, was interesting but may be purely an observational affect. The low incidence of congenital corneal abnormalities in the survey was expected, but the occurrence of a case of bilateral congenital corneal vascularisation was not. Acquired conditions were more common, even in such young foals, with direct trauma, entropion, foreign body, and exposure keratitis in unconscious foals, all being recorded. The rapid response to treatment in all these cases reflected the early evaluation and diagnosis possible because of examination soon after birth.

No detailed studies of subconjunctival (scleral) haemorrhages in the neonatal foal have been carried out previously although the conditon is well recognised in the equine and human neonate. The incidence in this survey was 8.3% , and this did not change with examination time after birth, within the 4 day limit. The possible relationship of retinal and scleral (subconjunctival) haemorrhages was not confirmed in this study and their occurrence together appears likely to be on a chance basis. Subconjunctival haemorrhages were not related to any neonatal foal abnormality including NMS, and there were no sex or eye distribution effects. In most cases the haemorrhages were fresh and red, and occurred mainly dorsal or dorso-nasally, with extension up to the limbus. Complete spontaneous resolution took 4-10 days depending on initial severity and extent. The pattern of resolution was very similar in all cases, both in size and colour changes and patterns. There was no affect on vision in the short or long term.

In this survey subconjunctival haemorrhage incidence was associated with foaling category, especially 3 and 4, multiparity and New Zealand bred foals. The latter relationship was thought to be due to increased birth weights and numbers in foaling categories 3 and 4, in this group. Both these factors could have lead to increased direct pressure on the orbit during vaginal birth passage, blunt optical trauma and subconjunctival haemorrhages. Multiparity is thought to be related to haemorrhage incidence because of the combined effects of increased birth weight, foetal oversize (increased head and thorax size), and increased speed and magnitude of delivery forces.

The results of this survey suggested that subconjunctival haemorrhages were probably a result of exaggerated normal changes seen in the periparturient neonate. As such, the main factors involved in the pathogenesis of these haemorrhages seem to be increased peripheral venous pressure due to thoracic compression and direct blunt ocular trauma during vaginal passage.

The vast majority of foals had a dark brown or grey-brown iris colour, of which 79% had a tan mottling especially towards the periphery. In the grey-brown group the mottling was more grey leading to an iridescent appearance. Homogenity was occasionally noted in the dark brown iris. These findings have been previously recorded in older foals and adults. The relationship between iris and coat colour was overall rather weak in this survey, however, specific trends of grey-brown and grey iris colour and iridescent appearance in chestnut and grey coat colours were identified. Iris pigmentation and appearance are related to nictitans colouration with pink black-edged nictitans more common in dark brown, mottled iris and whole pink forms in lighter iridial colours.

The resting, non-stimulated pupil in the neonatal foals in this survey was on average 75% or three quarters of the maximal degree of dilation. 50% of foals appeared to have 80% or greater of their maximal dilation. The resting pupil shape was related to pupil size, and in the young neonate was circular or a broadened oval. The size and shape of the pupil were related to the examination time. After stimulation of the PLR the pupil size and shape changes were very variable dependent on examination time, and generally less than expected in older foals and adults. The degree of dilation decreased by 5-15 points with a mainly oval shape.

4 foals were recorded with anisocoria, 2 of which had iris abnormalities and 1 had NMS. The disappearance of the anisocoria shadowed the improvement in clinical and neurological signs in this latter case.

All foals in this survey had dorsal corpora nigra and 74% had ventral structures. Dorsal corpora nigra were usually prominent and of normal size, which is proportionally smaller than that seen in the adult, whereas the ventral equivalent were small and difficult to detect. The lack of ventral corpora nigra in 25% of foals may be a reflection of size affecting detection, or development occurring post-natally.

Congenital abnormalities of the iris, other than persistent anterior pupillary membranes, were not found in this survey. 23% of foals examined had collarette tags of the anterior pupillary membrane but none had any remnants of greater length. The tags all arose from the mid iris region and were bilaterally symmetrical. 6 cases were intermittent and 8 complete. It was considered that these small persistent anterior pupillary membranes in the neonatal foals of this survey were similar to those seen in the adult, and represent incomplete or delayed resorption of a vestigial structure with no pathological significance. The two acquired iridial abnormalities were both cases of acute anterior uveitis, one as part of a neonatal septicaemia, the other due to severe blunt ocular trauma.

The lens' of the neonatal foals in this survey were normally completely transparent, but on close examination 50 of them had part of the pupillary membrane visible on the posterior capsule. The lens suture pattern was variable in this survey but 82% of foals had one or both visible on first examination. Definitive detection of the anterior suture was difficult and would have been helped by the use of the slit lamp biomicroscope, but overall focal illumination proved the most effective method of examinaton for suture patterns in this survey. Suture pattern shape varied around the basic theme of a Y shape and did not show the variety seen in previous surveys of older foals, however, differences in the examination procedure or in neonates may explain this.

25% of examined foals had remnants of the posterior pupillary membrane, often bilateral but not always symmetrical. Considerable variation in type and pattern occurred but, in general, there was a confluence towards the pole of the lens and the hyaloid artery origin. No abnormalities were detected in foal or eye in association with them and this survey concluded that they represent a normal variation, or delay, in the resorption of the foetal lens vascular system.

Their subsequent rate and degree of disappearance will require an additional study.

Although regarded as the most common ocular anomaly of the foal only 4 cases of congential cataracts were recorded in this survey. All were associated with other ocular abnormalities. No other congenital lens abnormality was detected. None of the foals had any visual deficits and all cataracts were non-progressive. Their precise aetiology was not defined. Two foals had acquired cataracts both as sequelae to severe anterior uveitis and anterior capsular debris deposition. In contrast to the congenital group these foals had systemic and visual abnormalities.

The normal appearance of the vitreous in the neonatal foal appears to be as in the adult with the exception of the presence of the hyaloid artery or remnants. Although several previous surveys of older foals have suggested that the hyaloid artery, or remnants thereof, are present in the majority of foals, this is the first study to analyse the type of structures found, their relationship to other ocular structures and pattern of resorption. Over 80% of foals in this survey had some part of the hyaloid artery present bilaterally and the degree of completeness, colour and character was statistically symmetrical. Unilateral incidence is uncommon and related to examination and regression period. The complete artery was present in just over 60% of foals.

Although New Zealand bred foals had a lower incidence of hyaloid arteries, an obvious reason for this is not known. Premature or dysmature foals with low birth weight have been suggested as having an increased incidence of hyaloid remnants but this survey did not confirm this. Examination period was related to the incidence of the hyaloid artery and its completeness, colour and character. Most of the foals with a hyaloid artery were seen in the first 48 hours of life and at this time the structure is most likely to be complete. This suggests that although atrophy of the system occurs in early neonatal life, and possibly pre-natally, it is still in the early stages at 2 days of age. This survey also confirmed that hyaloid artery structures do not generally cause ocular problems and, therefore, the presence of any such structure in the neonatal period is not an indication of abnormality or so-called persistence. 36% of foals in this survey had a red (blood filled) artery, 34.5% the clear version and 15% were black. The colour and character of the artery remnants were related to eachother and examination time, with red vessels in the first 24 hours, and clear structures in the 24-48 hour period. Complete systems are seen early in the examination period (<24 hours) and, as the system breaks down, the change in colour mirrors the extent of disruption.

None of the foals in this survey, in contravention of possibly ill-informed previous opinion, had any pulsations present within the artery whatever its colour or appearance. Statistical analysis of the results of this survey supported the view of a co-ordinated absorption/removal of blood from the system alongside its breakdown. Thinning of the hyaloid artery in those that were still complete was thought to be due to removal of the blood cells allowing vessel contraction, and/or compression of the mid-artery by the developing secondary vitreous. The pattern of breakdown was previously suggested as occurring in this mid-artery position but this survey's results were more confused with 62% of non-complete systems detached initially at the lens or optic disc. Remnants occur where detachment is not immediately adjacent to the lens or disc. Those present at the lens were most common.

The presence of the posterior pupillary membrane (PPM) was strongly correlated with the presence, completeness, colour and character of the hyaloid artery which is to be expected considering in reality the division between the two structures is purely for descriptive purposes. In general, extensive PPM's were associated with a complete, red hyaloid artery whereas less extensive or small remnants were likely to be related to a black, incomplete artery, particularly a lens remnant.

One foal had a congenital vitreal opacity associated with lens cataracts and fundic pathology, suggesting there had been in utero generalised posterior segment inflammation. Of great interest was the surprising lack of visual deficits in this foal and the non-progressive nature of the lesions despite their cause and severity.

The fundi of the neonatal foals in this survey were similar in many respects to that of the adult horse and older foal, although certain important differences were detected. There was a huge variation in the shape, character, appearance and colour of the optic discs within this survey. 60% of foals had pink, 25% pale pink and 14% red-pink optic discs and bilateral symmetry was present in all but 5 foals. 2 foals had orange coloured discs only previously recorded in adults.

In general, optic discs in neonatal foals were more red and homogenous than the adult horse and, although a change in colour with examination time was not established statistically, a trend of increasing paleness and heterogeneity of the disc with age did exist. No connection between optic colour and shape/character was established possibly due to the enormous variation in these parameters in this survey. Asymmetry in the disc character was again only detected in the same 5 foals and it appears that in both colour and character these unilateral changes are mainly related to conditions with a possible CNS component (retinal haemorrhages, papilloedema). Less variability in the range of descriptions applied to optic disc shape was recorded with the majority of foals having a regular oval. Other shapes that have been previously recorded were noted, but the considerable number of foals with larger than normal discs have not been. They are thought to be normal variations and of no significance. The range of optic disc characters was very wide and meant that many foals had combinations of categories to describe them. Many of these are seen in older foals and adults but 27% of foals had an homogenous appearance especially in the youngest foals, those with red-pink discs, and with papilloedema/retinal haemorrhages.

Papilloedema was recorded in 7 foals and a further 7 foals had a part, or parts, of the optic disc difficult to bring into focus with the ophthalmoscope. Most of the foals had bilateral changes which is likely to reflect increased intracranial pressure as a cause. Increased numbers of female foals were affected by papilloedema and retinal haemorrhages in this study although the reason for this is not understood. Papilloedema and abnormal foal behaviour were statistically related with a high incidence of Group 2 foal abnormalities. Papilloedema in these foals may be an indicator of cerebral oedema and/or increases in intracranial pressure. Category 3 and 4 foalings and multiparity also appear in this survey to be related to the incidence of papilloedema (and subconjunctival haemorrhages as well). Multiparity and papilloedema are both associated with increased birth weights and it is proposed that a combination of birth weight, relative foetal oversize (bone skeletal size rather than weight), and speed and magnitude of delivery forces, may lead to excessive mechanical stresses on the head and thorax of the foal. This may lead to increased venous pressure, and/or hypoxia, with concomitant cerebral oedema/increased intracranial pressure. A similar sequence of events is proposed for the pathophysiology of neonatal retinal haemorrhages and in this survey the incidence of these haemorrhages was strongly related to papilloedema occurrence. Reddening and homogeneity of the optic dsic and retinal vessel congestion and tortuosity were also shown to be connected to the incidence of papilloedema and retinal haemorrhages.

The majority of foals in this survey had a retinal vessel pattern as previously described for the older foal and adult horse. Patterns were generally bilaterally symmetrical and the majority of abnormalities detected were considered to be normal variations in individual foals unrelated to ocular or systemic pathology. Decreased numbers of retinal vessels of enlarged diameters were noted in a single case with congenital chorioretinitis and signs of posterior segment inflammation.

The tapetal fundus appearance varied enormously in the foals in this survey and differed to some extent from that seen in the older foal or adult. 16 different categories were used, often in combination, to describe the fundus. Bilateral symmetry was present in all but one foal. The most common tapetal colours were yellow-green, green with a yellow periphery, and yellow-orange with a green periphery. This is in contrast to the adult Thoroughbred where a blue-green tapetal colouration is most common. Variations in tapetal fundic colour did not appear to be correlated statistically with coat colour in this survey. Dorsal pigment mottling was detected in the vast majority of foals and the absence of, or decrease in, mottling was strongly associated with yellow tapetal colouration.

The Stars of Winslow were recorded in all foals where the fundus was visible. A relationship of tapetal fundic colouration to other pigmented areas of the neonatal eye was found, despite the negative effect of coat colour on the former. Green-yellow and yellow-green tapetal fundus colouration were related to whole-coloured pink nictitans, dark brown and grey-brown iris colour, dark brown non-tapetal fundus, and dorsal-to-disc depigmentation. Yellow-orange tapetal fundi foals had high numbers of pink black-edged nictitans and light brown-grey non-tapetal fundi. The tapetal and non-tapetal colouration was clearly related to the amount of pigmentation, with dark tapetal colours being associated with dark non-tapetal colours and vice versa.

42 foals in this survey had choroidal vessels visible in the fundus with the majority showing bilateral symmetry. The vessels were only seen in the area immediately dorsal to the optic disc running through the border into the tapetal fundus, and were very strongly related to dorsal-to-disc depigmentation of the fundus. Despite other surveys in older foals and adults stating that discrete choroidal vessels were infrequently seen, all 42 foals had parts of vessels visible. 88% of these were red or pink in colour with variations in colour related to the degree of depigmentation. Choroidal vessel incidence was related to tapetal/non-tapetal colouration, optic disc colour and border type. Of particular interest was

that with atypical colobomata which possibly indicates that local tapetal thinning and retinal pigment dilution in the peripapillary region is related to the retinal pigment epithelium defects in the colobomata. The two may be the same but occur in separate areas and to different degrees. The presence of choroidal vessels in the peripapillary region, without signs of fundic pathology, was not related to any foal abnormality or ocular defect.

There was an obvious demarcation between the tapetal and non-tapetal areas of the fundus in all the foals in this survey. In general, the border or junction was most obvious in the darker categories of tapetal and non-tapetal colouration. 87% of foals had a sharp straight changeover but 12.5% were noted as "ragged" or irregular in appearance. This latter irregular delineation has not been recorded in the adult horse. It is almost certainly due to the varied pigmentation of the RPE in this transition zone, and differences in the tapetum fibrosum thickness and extent. Border type was related to non-tapetal fundic colouration with straight forms more common in dark brown non-tapetum and ragged with grey-brown, especially with atypical colobomata. Some of this may be due to optical effects or, more interestingly, that variations in RPE and tapetum may manifest as both ragged border, dorsal-to-disc depigmentation and atypical colobomata in foals especially with less pigment in their non-tapetal fundi.

The majority of foals in this survey had dark brown non-tapetal fundi with 20% a lighter grey-brown colour. In most cases the non-tapetal fundus was homogenous in colour and appearance, although dorsal-to-disc depigmentation was common and variable in extent and degree. The combination of colour and appearance in the non-tapetal fundus resulted in 11 categories being derived with some containing only small numbers of foals. Foal coat colour and tapetal colouration were related in this survey to non-tapetal fundic colour/appearance. Dark brown/homogenous and dark brown/dorsal-to-disc depigmentation non-tapetal fundi are more commonly found in bay foals, with yellow-green/dorsal mottled and green-yellow/dorsal mottled tapetal fundi, respectively. Chestnut and grey foals are more likely to have brown-grey/+/- dorsal-to-disc depigmentation non-tapetal fundi with a yellow-orange green border/dorsal mottled tapetal fundi. Further analysis of ocular colouration and non-tapetal fundus colour and appearance confirmed and developed previously suggested connections. Nictitans and iris colour were related to non-tapetal fundus description through the common denominator of coat colour. Dark brown/homogenous non-tapetal fundi were more commonly associated with pink/black-edged nictitans and dark-brown iris, whereas grey-brown +/- dorsal-to-disc depigmentation was related to whole-coloured pink nictitans and grey-brown iris.

The incidence of congenital fundic abnormalities was high in this survey but only one foal had apparent visual deficits which were temporary. Atypical colobomata were common and the majority of lesions were in the thin area of non-tapetal fundus between the level of the disc equator and the horizontal border. Only 2 foals had colobomata in the main part of the non-tapetal fundus. There was no bias towards unilateral or bilateral incidence. All lesions appeared quiescent with no evidence of posterior segment inflammation. The colobomata were very varied in appearance with usually one or two lesions of a small round or medium-sized, ragged or uneven appearance with reasonable bilateral symmetry. Any retinal vessels traversing the area of colobomata appeared unaffected and no visual deficits were recorded.

The incidence of atypical colobomata in this survey was statistically related to the occurrence of a ragged border between the two fundi, and dorsal-to-disc depigmentation, both of which are normal variations in the tapetum and RPE. This survey's results suggest that atypical colobomata are normal variations in the degree of retinal and choroidal pigmentation, and tapetal extent occurring during embryogenesis as minor abnormalities and normal variations, particularly in the border and peripapillary regions.

No surveys of neonatal retinal haemorrhages in the domestic animals has been undertaken until this study. Many such studies have, however, been carried out in the human neonate and comparison of findings between the two species was undertaken to give some insights into the morphology and cause of the equine condition. The incidence of retinal haemorrhages in this survey was 16% with 90% of foals examined within 48 hours of birth. Careful examination of the fundus, experience in differentiating haemorrhages from other lesions, and random selection of foals from normal populations were all considered important in their likely affect on incidence. The concentration on the Thoroughbred breed only may have biased the results and a wider, larger survey across all breeds might show interesting differences. There was no statistical connection between subconjunctival (scleral) and retinal haemorrhages in this survey. Eye distribution of retinal haemorrhages in this survey was not statistically different but bilateral haemorrhages were more common than unilateral, especially in females, and with increased numbers of haemorrhages. There was a statistically significant increased number of female foals with retinal haemorrhages in this survey. The reason for this is unclear although it is postulated that birth weight may be a factor. Smaller than average female foals may be subjected to increased intrauterine pressures whereas large size, especially in head circumference, may be significant in male foals.

Numbers of retinal haemorrhages varied from 1 to greater then 20, but just over 50% of foals were in the 1 to 5 group. Involvement of both eyes became more likely as numbers of haemorrhages increased. Small numbers of haemorrhages are easily missed. Several cases had differences between eyes in numbers, distribution pattern and type of haemorrhages and may relate to individual anatomic variants in pathogenesis. 38% of eyes with retinal haemorrhages had the small punctate type whilst 56% had the splash-like form. 3 foals had a mixture of both. The type of haemorrhage which occurs appears to be related to the numbers present, with the punctate type seen in low numbers and splash-like haemorrhages when numbers are greater than 10. There is no change from one type of haemorrhage to another, and both undergo similar patterns of resolution.

The level within the retina at which the haemorrhages occur in the foal is not known and will require a detailed histological study to clarify this. It is postulated that in the peripapillary region and the optic disc itself they may be derived from the retinal circulation and, therefore, be intraretinal. The possibilities of haemorrhage occurring at the subretinal level appear unlikely since after resolution no evidence of RPE changes have been found. Choroidal haemorrhages would require to be at the level of the choriocapillaris to be visualised in the tapetal fundus.

All retinal haemorrhages, except the 2 foals with optic disc haemorrhages, were located in the tapetal fundus, although their presence in the non-tapetal fundus may have been obscured physically or visually, depending on the level of the haemorrhage. The distribution and numbers of retinal haemorrhages were statistically related with low numbers in a discrete area close and dorsal to the optic disc. As numbers increase, the distribution is more widespread. Both the optic disc haemorrhages were the single small splash-like forms and behaved in a similar manner to the other retinal haemorrhages.

14 foals were recorded with acute haemorrhages and 17 had resolving types. There was no relationship between the stage of resolution of the

haemorrhages and initial examination time although at subsequent examinations increasing numbers of foals showed evidence of resolution. The more rapid resolution of haemorrhages in some foals may be due to a difference in type of haemorrhage, or individual foal effects. A further histological study is required to document the pattern of resolution.

The rate of change, and ultimate resolution, of retinal haemorrhages in this survey was quite variable and provisional conclusions are that, in general, large numbers of haemorrhages and large splash-like types took longer to resolve. Peripheral haemorrhages resolved first. The pattern of resolution was centripetal with the onset of resorption visible initially as the margins of haemorrhage become more indistinct. Acute haemorrhages were usually red or red-purple with sharp edges, becoming mauve-purple and less well defined within 2-3 days. The numbers and size of haemorrhages were at this stage as in the acute phase, although small haemorrhages may have already disappeared. Over the next 3-5 days the haemorrhages become even paler and more diffuse with decreases in number and size. All haemorrhages had resolved by 10 days of age.

A number of factors were found in this survey to have an affect on the incidence of retinal haemorrhages. Low birth weight, especially in foals with prematurity/dysmaturity had a distinct decreased incidence of retinal haemorrhages whereas larger body weight, and probably increased cranium size, in male foals appeared to have an increased incidence. Measurement of cranial circumference in male and female foals would have been a useful parameter to measure. The incidence of asphyxia during the birth process in the foals in this survey was difficult to assess because of the type of examinations carried out, but may be important in the aetiology of haemorrhages. Coagulopathies within the foals with retinal haemorrhages were not detected. There was a significant association between foaling category and the occurrence of retinal haemorrhages especially in those with prolonged second stage and/or increased compression on the head and thorax. There is no relationship to parity or gestational abnormalities. Retinal haemorrhages had no statistical relationship with the presence of any other perinatal ocular haemorrhage or pathology, except papilloedema. Papilloedema, red-pink optic disc colour and homogenous disc character, and retinal vessel congestion and tortuosity are all statistically related to the presence of retinal haemorrhages and may have a common pathophysiology of increased intracranial pressure. Finally, there appear to be no long term ocular or neurological effects of retinal haemorrhages and no connection with abnormal foal behaviour.

Based on data accumulated by this study an hypothesis of the pathogenesis of neonatal foal retinal haemorrhages is proposed which is complicated, interrelated and has multiple facets with various factors of greater or lesser importance in individual animals. It is suggested that increases in intracranial pressure brought about by foetal head compression and increases of central venous pressure due to thoracic compression, may be one of the major factors involved. Intracranial pressure increases will lead to increased intravascular pressures, elevated cerebrospinal fluid pressure and cerebral oedema. Thoracic compression will also elevate CSF pressure. An affect of cerebral oedema and CSF pressure changes is papilloedema. Intravascular pressure changes, CSF pressure fluctuations and cerebral oedema may all lead to haemorrhage both in the general circulation of the head and, more specifically, in possible predisposed pathways such as the retinal or choroidal circulation.

Anoxia/asphyxia can potentiate these effects by increasing vessel fragility and vasodilation, and leading to metabolic acidosis. The latter leads to profound changes in cerebral blood flow and ischaemia, with decreased cardiac output and increased peripheral vascular resistance. Other possible factors may include individual anatomic variations in blood supply and vascular fragility, and low grade coagulopathies.

As in any project, certain specific goals were set and some were met and others were not. Some questions were answered and new ones posed. Ideas for other studies became clearer as the data was analysed. The project would have been improved by examining larger numbers of foals, more serial examinations, better access to a fundic camera and slit lamp biomicroscope, slightly clearer definition of the categories of study eg. scleral shelf and pectinate ligament insertions, and greater assistance from a biomedical statistian at the design stage of the survey. Although the numbers of foals examined was quite small, the initial hope to document the normal appearance of the neonatal Thoroughbred foal's eye and its differences from the adult was substantially achieved and hopefully this will be of help to the equine veterinary profession. Examination of greater numbers of neonatal foals of all equine breeds would be useful in the future to confirm the initial results of this survey, particularly as regards ocular pigmentation and subconjunctival/retinal haemorrhages. The incidence of congenital anomalies and abnormalities would also benefit from this wider study for this survey very clearly demonstrated that many are uncommon and not readily available for examination. Some of the abnormalities suggested in previous studies appear to be little more than variations from the normal mean in this survey and this will hopefully put some clinicians minds at rest. To this end further histological studies to document the actual cellular structure of ophthalmoscopic variations, especially in the fundus, is essential and would possibly quieten often subjective opinion. A histological study of the reabsorbing hyaloid artery would also help further understand this process and possible variations from normal. The adaptation of the neonatal eye to the older foal or adult model was touched on in this survey but further study incorporating serial examinations over varying periods, possibly 0-21days, would be useful in obtaining information on the ocular reflexes, resorption of the hyaloid and pupillary membrane systems, and the resolution of subconjunctival and retinal haemorrhages. Embryological studies of the horse's eye have yet to be performed and much awaits to be discovered regarding the mechanism of the development of the eye and hence, congenital ocular defects in the horse. This area will form the basis of the authors' post doctoral research with a light and electron microscopic study of the eye of the equine embryo and foetus. Further development of the project may be possible by following neural crest cell migration using immuno-histochemical staining techniques. In the fascinating condition of neonatal retinal haemorrhages a great deal could be gained by a histological study of the source and resolution of the haemorrhages. Information gained from this source and that obtainable from a detailed study of the parturient period would substantially help towards a better understanding of the aetiology of retinal haemorrhages. Possible areas of study might include foetal blood pressure, foetal head compression values, head and thorax circumference and the length of second stage parturition. This survey, however started the process, already present for a century in medical science, of documenting the morphology, incidence, resorption and possible aetiology of this condition in the equine neonate. The quest continues.

A CLINICAL AND MORPHOLOGICAL STUDY OF THE NEONATAL THOROUGHBRED FOAL'S EYE.

VOLUME II

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TABLE OF CONTENTS.

LIST OF FIGURES.

34. Bay, abnormal foal with septicaemia, 72 hours old. The right eye of this foal is shown immediately after the lower eyelid has been manipulated into a normal resting position. Both eyelids, which had secondary entropion, were treated similarly on a regular basis by the stud groom. Note the excessive lower eyelid fold and orbital sulcus, with wetting of the face due to excessive lacrimation and ocular discharge. **406**

35. Bay, abnormal foal with septicaemia, 6 days old. See figure 34. The resolving, secondary entropion of the right eye is retracted ventrally to reveal the green-yellow hypopyon up to the level of the ventral pupillary margin. The globe is already soft and smaller than normal. Note the lower vibrissae. **407**

36. Bay, abnormal foal with septicaemia. Post Mortem examination of the right hip joint after euthanasia at 14 days old. Note the severe damage to the articular cartilage of the femoral head due to the septic arthritis/osteomyelitis secondary to the neonatal septicaemia. **408**

37a. Chestnut, abnormal, 12-24 hour old foal. This NMS foal suffered from severe self-inflicted trauma, including around both eyes. This figure shows the left external eye with severe excoriation of the eyelids, swelling and inflammation. The globe was withdrawn and a manually resolvable, secondary entropion was present. **409**

37b. Chestnut, abnormal, 12-24 hour old foal. This NMS foal suffered from severe self-inflicted trauma, including around both eyes. This figure shows the right external eye with only mild excoriation on the lower eyelid. **410**

46. Chestnut, normal, 15 minute old foal. This view shows the lower eyelid orbital sulcus and vibrissae, absent lower lid cilia and, still wet, long dense, upper cilia. On the temporal side of the pupil is a small dark posterior capsular remnant of the hyaloid artery. **419**

47. Chestnut, normal, 6 hour old foal. This view clearly shows the dorsal and ventral orbital sulci and unpigmented eyelid margins. The long, dense upper and short, sparse lower cilia are visible, as is a single vibrissae running downwards across the eye near the temporal canthus. A 75% oval, slightly wider nasally pupil, and whole-coloured pink nictitans are also seen. Note the normal diameter, complete, clear hyaloid artery on the nasal (medial) side of the pupil. **420**

48. Chestnut, normal, foal. A 50-60% oval post-stimulation pupil is visible in this typical eye of a chestnut foal, with unpigmented eyelid margins, whole-coloured pink nictitans, unpigmented limbal area and mottled grey iris. The long, dense upper and short, sparse lower cilia are also typical. **421**

49. Light chestnut, normal, 17 hour old foal. A grey, mottled iris with 2, dorsal, moderate, irregular corpora nigra. The pupil is 70-75% elliptical. A whole coloured pink nictitans and pink caruncle are visible in the nasal canthus. The long, dense, upper cilia are prominent with the short and sparse lower cilia most obvious nasally against the unpigmented lid edges. **422**

50. Chestnut, normal, 15 hour old foal. This view of the external eye shows a folded lower eyelid in the right eye (excessive orbital sulcus) with palpebral margins in normal opposition to the cornea. The lower lid vibrissae are seen ventrally and the long upper cilia radiate over the palpebral fissure. No lower cilia are present. **423**

51. Chestnut, normal, 18 hour old foal. This external view shows the upper eyelid orbital sulcus, vibrissae (approx. 4) and long, dense upper cilia. The whole-coloured pink nictitans is seen in the nasal canthus. 424

52. Chestnut, normal, 11 hour old foal. A single dorsal vibrissae, long and dense dorsal cilia, short sparse lower cilia, and approximately 6 ventral vibrissae are seen in this view. The unpigmented eyelid margins are particularly obvious. The pupil is 70% oval. 425

53. Chestnut, normal, 12 hour old foal. The palpebral fissure shape, dorsal and ventral orbital sulci, and upper and lower eyelid cilia are all seen in this external eye view. In the temporal canthus, just to the inner side of the mildly pigmented limbus, is a smokey grey line representing the insertions of the pectinate ligaments. The grey-brown iris with iridescent pupillary margin and normal dorsal corpora nigra is seen surrounding a 70% oval pupil. 426

54. Bay, normal, 28 hour old foal. This view shows a pink black-edged nictitans, moderate sized dorsal and small ventral corpora nigra, and 75% oval pupil. Note also the heavily pigmented eyelid margins. 427

55. Bay, normal, 13 hour old foal. The left eye of a foal with unilateral scleral (subconjunctival) haemorrhage in intermittent patches across the entire dorsal sclera, but more intense nasally. Except nasally, the haemorrhage does not extend to the limbus. Long cilia and entrances to the Meibomian glands are seen in the upper eyelid. Pigmentation of the sclera only occurs at the limbus. A scleral overhang or shelf is seen dorsally midway between the canthi. A mottled dark brown iris, with a blue-grey iridescence near the pupillary margin, and prominent dorsal corpora nigra are also seen. **428**

56. Bay, 11 hour old foal, showing mild neurological signs including head tilt, dumbiness and bumping into objects. Above average birth weight with category 3 foaling. The foal recovered to normality in 48 hours with intensive care. This view of the right eye demonstrates clearly the red, fresh, patchy, mild subconjunctival haemorrhage in the dorso-nasal region of the sclera. The haemorrhage barely reaches the limbus (except nasally) and is accompanied by superficial scleral and bulbar conjunctival vessel injection. Note the fresh, slightly more obvious, haemorrhage alongside the enlarged vessel in the centre of the photograph. Also visible is a reddened and inflamed palpebral conjunctiva, pink black-edged nictitans, meibomian gland entrances on the upper eyelid, and long upper cilia. **429**

57. Chestnut, normal, 13 hour old foal. The normal palpebral fissure shape; long dense, dorsal and short, more sparse, ventral cilia; and dorsal vibrissae are all visible in this foal. The unpigmented eyelid margins, whole-coloured pink nictitans and grey-brown/iridescent pupillary margin iris, are all typical of chestnut foals. The 65%, almost elliptical, pupil shape is clearly seen, as is the dorsal and ventral corpora nigra. The translucent remnants of the posterior pupillary membrane are seen in the temporal margin of the pupil. **430**

58. Chestnut, normal, 18½ hour old foal. This view of the nasal canthus demonstrates unpigmented eyelid margins, long dense upper and short sparse lower cilia, a small unpigmented hairless caruncle, a whole-coloured pink nictitans, unpigmented sclera, nasal pectinate ligaments but no grey lines of insertion into the cornea, a grey-brown mottled iris, normal-sized dorsal and small ventral corpora nigra, and a 70% oval pupil. Note the translucent remnant of the posterior pupillary membrane. **431**

59. Bay brown, normal, less then 24 hour old foal. This left eye shows a primary entropion of the lower eyelid which was treated by regular manipulation and antibiotic ophthalmic ointment. It successfully resolved in 48 hours. Also note the 50-60% elliptical pupil, large dorsal corpora nigra, dark brown mottled iris, and thin, dark, lace-like, pupillary membrane collarette just visible in the anterior iris temporal to the pupil. **432**

60. Chestnut, abnormal, less than 24 hour old foal. This foal was born with a Group 3 developmental problem involving flaccid tendons of both front and hindlimbs. Subsequently, a bilateral entropion with severe mucopurulent ocular discharge developed. At this stage the entropion is resolved but the dried mucopurulent ocular discharge is evident around the eye, on the eyelids and cilia. **433**

61. Grey, normal, 16½ hour old foal. This view of the nasal canthus shows a pink black-edged nictitans, darkly pigmented caruncle and eyelid margins, dark grey mottled iris with iridescent pupillary margin, and normal sized dorsal corpora nigra. The pupil is 70-75% and oval. Adjacent to the edge of the nictitans is a light blue line, which is the pectinate ligament insertion. **434**

62. Chestnut, normal, 59 hour old foal. This older foal has a more adult type pupil in shape and size (60% oval). The entrances to the meibomian glands are particularly clear in the nasal aspect of the upper eyelid. The everted palpebral conjunctiva is of a normal colour and appearance. A pink whole-coloured nictitans, non-pigmented white sclera, and grey-brown iris with pupillary margin iridescence, are all clearly visible. The dorso-temporal iris has a short persistent pupillary collarette seen as a thin dark line just peripheral to the iridescent margin. Due to the lack of limbal pigment the dorsal scleral shelf is obvious, and just visible are some whitish pectinate ligaments towards the temporal canthus. **435**

63. Bay, normal, 40 hour old foal (see figure 66). The right eye of the foal with corneal vascularisation is shown after a further 24 hours. The bulbar and palpebral conjunctival inflammation has decreased but the vessel injection is still obvious. The limbal pigmentation and pectinate lines are especially clear. The density of the vascularisation has decreased, with individual vessels being seen and the edges becoming more diffuse. The connecting discrete corneal vessels have almost completely disappeared, leaving a clear corneal gap. Note the hair foreign body on the cornea. 436

64. Strawberry roan, 2 month old, Welsh Mountain foal. This foal was born with a posteriorly dislocated lens. The foal has a heterochromia irides with pupil distortion. The variable accumulation of pigment at the limbus is particularly obvious. 437

65. Bay, normal, foal. A heavily pigmented nictitans edge is visible in the nasal canthus. The sclera is pigmented in patches with intermittent concentration at the limbus. Adjacent to this limbal pigment is the blue line of the termination of pectinate ligaments in the cornea. 438

66. Bay, normal, 16 hour old foal. The right eye of this foal shows a reddened, inflamed upper palpebral conjunctiva and injected bulbar subconjunctival vessels with a reddened sclera. There is prominent dorsal limbal pigment accumulation and pectinate lines. Nearly the entire length of the dorsal limbal cornea, some 3mm inwards fram the limbus, is affected by a solid fringe of corneal vascularisation or pannus. This is connected to the limbus by discrete straight corneal vessels. 439

67. Bay-brown, normal, 16 hour old foal. The slightly everted upper eyelid shows the long dense cilia of this lid, and mildly swollen, reddened palpebral conjunctiva. In the centre of the pupil the upper part of the Y suture can just be discerned. 440

68a. Bay, normal, 34 hour old foal. Subconjunctival haemorrhages overlying dorsal sclera. There are two discrete areas, dorso-temporal (68a) and dorso-nasal (68b), of fresh, red, patchy haemorrhage which run up to, and are slightly denser at, the limbus. 441

68b. Bay, normal, 34 hour old foal. Subconjunctival haemorr hages overlying dorsal sclera, dorso-nasal. 442

69. Chestnut, normal, 38 hour old, foal. This left eye has a pink, black-edged nictitans. 443

70. Chestnut, normal, 38 hour old foal. The right eye (see figure 69) has a whole-coloured pink nictitans. Note the unpigmented sclera and longer, more dense, lower eyelid cilia in this eye. 444

71. Chestnut, normal, 15 minute old foal. This view shows the unpigmented eyelid margins, pink with black edge nictitans, and unpigmented nasal canthal sclera. The pupil is 70% oval and there are 3 very prominent dorsal corpora nigra. Part of the Y shape of the posterior suture pattern of the lens is visible. 445

72. Bay-brown, normal, 15 minute old foal. A pink, black edge nictitans, unpigmented dorsal sclera and reddened palpebral conjunctiva are seen in this view. Within the pupil, Y-shaped, translucent, almost ghost-like, persistent pupillary membranes are seen on the posterior capsule of the lens. 446

73. Bay, normal, 40 hour old foal (see figure 78). The left eye of the foal with corneal vascularisation is shown after a further 24 hours. The bulbar and palpebral conjunctival inflammation has decreased markedly with only slight injection in the palpebral vessels. In a similar way to the right eye, the corneal vascularisation has decreased in density, with no visible connecting corneal vessels to the limbus. The areas of vascularisation in this eye are more diffuse and patchy, with no individual vessels being evident. 447

74. Bay, normal, 31 hour foal. The left eye showing the detached clear remnant of the hyaloid artery on the posterior lens, just to the nasal side of the centre. A small, translucent, posterior pupillary membrane is present, immediately adjacent to the pupillary margin ventro-temporally. The pupil is 80% round, with a slightly small dorsal corpora nigra, and a grey-blue (especially pupillary margin) iris. Note the prominent limbal pigmentation and palpebral shape. 448

75. Dark brown, normal, 14 hour old foal. Besides a very dark brown, mottled iris colour, this foal had excessive amounts of pigmentation in its sclera. It is not possible from this view to detect the limbus. 449

76. Bay, normal, 6½ hour old foal. This view of the temporal canthus shows a dark brown, mottled iris, prominent dorsal corpora nigra, mild patchy scleral pigmentation, intense limbal pigment, and the start of a scleral shelf dorsally. 450

77. Bay, normal, 60 hour old foal. Magnified view of the dorso-nasal sclera and nasal canthus. A pink, black-edged nictitans and hair arising from the caruncle are seen within the canthus. The accumulation at the limbus, and mild peppering of pigment in the sclera is shown with normal episcleral and bulbar conjunctival vessel appearance. 451

78. Bay, normal, 16 hour old foal. The left eye of this foal shows a reddened, inflamed, upper palpebral conjunctiva and injected bulbar subconjunctival vessels with a reddened sclera. There is prominent dorsal limbal pigment accumulation and, immediately adjacent, a blue-grey line representing the insertion of the pectinate ligaments. Careful scrutiny of the dorsal cornea, especially on the nasal side, reveals 3 areas of corneal vascularisation or pannus. 452

79. Diagram of the Schirmer tear test, which involves inserting a test strip into the conjunctival sac and measuring the length of absorption along the paper. 453

80. A histological cross section of a normal cornea of a foal. The layers from the top downwards are: 1) The non-keratinised stratified squamous epithelium and its basement membrane; 2) The corneal stroma consisting of stromal cells and collagen lamellae; 3) The elastic Descemet's membrane, which acts as the basement membrane for; 4) The single layer endothelium. 454

81. A photomicrograph of the iris, ciliary body and cornea of a foal's eye. The multilayered cornea is seen to the right. Situated at the pupillary margin is the dorsal corpora nigra, which is an extension of the heavily pigmented posterior pigment epithelium of the iris, . The iris sphincter muscle is seen in the central stroma near the pupillary margin and corpora nigra. The heavily pigmented pars plicata of the ciliary body is seen below the iris, and contains large numbers of fenestrated blood vessels. 455

82. Schematic diagram to show how Persistent Pupillary Membranes (PPM) may float freely in the anterior chamber and/or be attached to other sites on the iris, lens or cornea (after Lavach, 1990). 456

83. A subpalpebral lavage system and third eyelid flap used in an adult thoroughbred with a chronic, corneal ulcer. **457**

84. A 6 month old, Thoroughbred foal with a large perforating wound of the cornea from limbus to limbus. The wound is plugged by iris, fibrin and other exudate. Note the thickened, oedematous corneal edges and injected scleral blood vessels. **458**

85. Bay, normal, 2 hour old foal. In the nasal (medial) canthus a nictitans with a pink, black edge colouration is clearly visible, partially overlying the sclera which has a prominent limbal accumulation of pigment. Immediately adjacent to the limbus is a blue-grey line representing the insertion of the pectinate ligaments. The dark brown iris has a bluish iridescence adjacent to the dorsal corpora nigra. Note the mild, ventrally rotated, nasal pupillary fissure. **459**

86. Bay-brown, normal, 16 hour old foal. A detailed view of the temporal canthus shows the blue-grey line of the insertion of the pectinate ligaments, a dark brown iris with very short collarette of persistent pupillary membrane, and limbal pigmentation. **460**

87. Chestnut, normal, 59 hour old foal. A magnified view of the dorsal limbus clearly demonstrates the scleral shelf or overhang, and lack of limbal pigment. **461**

88. Bay, normal, 88 hour old foal (see figures 63 and 66) The right eye of the foal with corneal vascularisation 48 hours after the second examination. The conjunctivae are less inflamed. The vascularisation has decreased in size (both length and width), is more diffuse with less evidence of individual vessels, and the limbal gap has increased. **462**

89. Bay, normal, 88 hour old foal (see figures 73 and 78). The left eye of the foal with corneal vascularisation 48 hours after the second examination. The conjunctivae are less inflamed. The patches of vascularisation have become smaller (length and width) and more separated, and the limbal gap has increased. 463

90. Bay, underweight, dull, abnormal, 14½ hour old foal. The left eye of the foal clearly shows the tightly coiled hairs resting on the cornea. Notice the excessive lacrimation especially from the nasal canthus, and matting together of the upper cilia. 464

91. Bay, underweight, dull, abnormal, 14½ hour old foal. The hair foreign body has been removed from the right eye. The resultant round, superficial ulcer is clearly visible in the centre of the cornea just above the lower eyelid. The mildly underrun edges of the ulcer (dense opacity) are surrounded by a larger, more diffuse, corneal oedema. Superficial vascularisation of the cornea is seen as a fringe of arborising vessels arising from the dorsal limbus. Also clearly visible is the mottled dark brown iris, intensely pigmented limbus, and long, dense upper cilia. 465

92. The foreign body removed from the right eye shown alongside a scalpel blade handle. The offending article is a tightly coiled ring of strands of hair which is concave on the corneal surface. 466

93. A schematic diagram of the sclera. 467

94. Chestnut, normal, 16½ hour old foal. Fresh, red, patchy, dorsal temporal subconjunctival haemorrhages with bulbar conjunctival vessel injection. 468

95. A higher powered photomicrograph of the central section of a foal's iris. The bottom densely pigmented line is the double epithelial layer seen resting on their basement membranes. The stroma comprises the bulk of the iris, and contains melanin pigmented cells distributed throughout. Also present is connective tissue, large numbers of blood vessels and nerves. The anterior border or endothelial layer is thrown into folds by the contraction of the dilator muscle. **469**

96. Strawberry roan, 2 month old, Welsh Mountain foal (see figure 97). This foal has a posteriorly dislocated lens which has a nuclear cataract. The sheets of material outside the lens equator are the damged lens zonules. The pupil is distorted in shape and larger than would be expected in this age of foal. The heterochromic iris is different in colour and appearance to the normal eye (see figure 97) and the corpora nigra are shrunken and misshapen. The radial iris vascular pattern is visible through the lightly pigmented iris. **470**

97. Strawberry roan, 2 month old, Welsh Mountain foal (see figure 64). This is the normal other eye in this foal affected by a congenital lens dislocation. The heterochromia irides and dorsal/ventral corpora nigra are obvious. Notice the difference in shape and size of the latter in this non-affected eye. The pink fundic reflection was due to partial albinism in the tapetal/non-tapetal fundic colouration. **471**

98. Bay, normal, 13 hour old foal. A pink with black edge nictitans is obvious in the nasal canthus. An 80% round pupil is present with a normal sized dorsal corpora nigra. The iris is grey-brown especially towards the pupillary margin. In the ventral part of the pupil, an inverted L shaped, translucent posterior pupillary membrane is present with small amounts of debris at the angle of the vessels. This was associated with the hyaloid artery in figure 138. **472**

99. Peripapillary fundus of a palomino pony (see figure 201) with heterochromia iridis. This subalbinotic fundus has a pale yellow tapetal fundus with red Stars of Winslow, an indistinct border, non-pigmented non-tapetal fundus with prominent red choroidal vessels. The pale, normal shaped optic disc has an indistinct retinal vessel vasculature pattern with two areas ventrally which appear unfocused. These may represent myelin extension from the disc. **473**

100. Schematic diagram of the three types of cyst arising from the equine iris: A = Cysts of the posterior pigment epithelium, some of which may break off and float through the pupil; B = Stromal cysts often associated with stromal atrophy; C = Cysts of the corpora nigra (after Lavach,1990). **474**

101. Chestnut, normal, 11 hour old foal. An obvious foreign body of hair and mucoid material is resting on the ventro-temporal cornea. This material lodged on the cornea after examination and before photography. No corneal abnormalities were present and it was easily removed. Note the dense and long upper cilia, and dorsal orbital sulcus. The pupil is approximately a 70% oval. **475**

102. Bay, normal, 2 hour old foal. The normal position of the upper and lower eyelids in relation to the cornea are visible. The iris is overall a dark brown colour, with prominent iridescence dorsally, and some pigment mottling. The pupil is between 60-65% oval, with an obvious dorsal corpora nigra. On the dorso-temporal iris there is a small remnant of the pupillary membrane. **476**

103. Bay, normal, 60 hour old foal. The nasal portion of the lens of the left eye has prominent nuclear rings and ventrally bubbly vacuolation. There is disruption of the lens cortex ventrally and evidence of debris on the lens towards the equator (centre). The pupil is 70% oval. Note the small dorsal corpora nigra. **477**

104. Bay, normal, 6½ hour old foal. A dark brown mottled iris with slight pupillary iridescence and moderate sized dorsal corpora nigra is evident. The pupil is between 75-80% and round. **478**

105. Bay, normal, 11 hour old foal. A 75% oval pupil with a normal size dorsal corpora nigra. **479**

106. Chestnut, normal, 18½ hour old foal. A pigmented, focal opacity of the anterior lens capsule is present just dorsal to the very small ventral corpora nigra, in the ventral pupil. Temporal to this are inverted Y, translucent remnants of the posterior pupillary membrane. The pupil is 70-75% and oval. **480**

107. Chestnut, normal, 39 hour old foal. The iris is grey-brown with an iridescent pupillary margin, and normal-sized dorsal corpora nigra. The pupil is 60% elliptical. This left eye canthus contains three areas of posterior pupillary membrane on the posterior capsule of the lens, seen against the pale pink reflection of the optic disc. **481**

108. An adult Thoroughbred with homogenous dark brown iris, elliptical pupil and moderate sized dorsal and ventral corpora nigra. **482**

135. Bay, normal, 20 hour old foal. On the posterior capsule of the pupil there is a focal, mildly opaque area which is associated with a small, translucent hyaloid artery remnant. **513**

136. Bay-brown, normal, 16 hour old foal. A thin, translucent, floating hyaloid artery is seen running transversely across the equator of the pupil. **514**

137. Bay-brown, normal, 16 hour old foal. This peripapillary view shows a normal-shaped pink optic disc with a slightly light centre and mid-ventral white rim. Very careful scrutiny reveals a thin straight line in the centre of the disc. This is a complete, thin, translucent hyaloid artery running from the disc towards the camera. Dorsal to the disc the dark grey-brown non-tapetal fundus is mildly depigmented and several straight, linear choroidal vessels are evident running towards the straight, normal border. The green yellow tapetal fundus has several blue spots visible which are probably end-on choroidal vessels. **515**

138. Bay, normal, 13 hour old foal. From the centre of the red-pink optic disc a red linear structure can be seen running towards the camera. This represents a complete, thin, red hyaloid artery. The dark brown non-tapetal fundus, normal straight border, and green yellow tapetal fundus are all seen clearly. The area dorsal to the disc has depigmentation, choroidal vessels and green streaking into the tapetal fundus. The lines running vertically across the photograph are due to the excessively long upper eyelid cilia obstructing the camera view. **516**

139. Chestnut, normal, 13 hour old foal. A normal, black, complete hyaloid artery is seen curving from the optic disc to the posterior lens. This was seen to move as the foal's head position shifted. **517**

140. Bay, normal, 20 hour old foal. A normal diameter, complete, red, hyaloid artery is seen running towards the lens from the disc. This vessel appeared to float as the foal's head was moved. 518

141. Chestnut, normal, 18½ hour old foal. The pale pink, normal-shaped optic disc has a light centre and border with a slight dorsal extension. In the centre is a fine straight line representing the thin, red, complete hyaloid artery. The retinal vessels are particularly obvious in the non-tapetal fundus near the atypical coloboma. Notice also the dorsal-to-disc depigmentation, ragged border and start of green-yellow tapetal fundus. 519

142. Chestnut, normal, 18 hour old foal. The very short and sparse lower cilia, and unpigmented lid margin are shown. The complete, thin, translucent hyaloid artery is seen running away from the lens in the nasal side of the pupil. 520

143. Photomicrograph of cross section through the tapetal fundus and choroid. Note in the upper part, the retina (see figure 28 for structure). The non-pigmented retinal pigment epithelium is in intimate contact with the vascular choriocapillaris. Immediately beneath this is the tapetum consisting of parallel orientated collagen fibrils. Note the large vessel passing through the tapetum towards the choriocapillaris and immediately beneath this the heavily pigmented suprachoroidea and lamina fusca. 521

144. Higher powered photomicrograph of cross section through the tapetal fundus and part of choroid. Note the non-pigmented retinal pigment epithelium in intimate contact with the photoreceptor layer of the retina. Immediately beneath is the vascular choriocapillaris and tapetum. 522

145. High powered photomicrograph of cross section through the non-tapetal fundus and choroid. Note the heavily pigmented retinal pigment epithelium and closely associated choriocapillaris. The tapetal layer is absent and the pigmented suprachoroidea is immediately below the choriocapillaris. **523**

146. Chestnut, normal, 15 minute old foal. A view of the fundus showing extensive dorsal and peripheral pigment mottling and category 2 tapetal fundic colour (yellow, slight green periphery). **524**

147. Chestnut, normal, 18 hour old foal. This peripapillary view shows a yellow green tapetal fundus with greenish Stars of Winslow, straight border and dark brown non-tapetal fundus with a considerable area of depigmentation dorsal to the optic disc. The disc is normal-shaped and pink, with a light centre and border, mid-ventral white rim, obvious retinal vessel pattern, and accumulation of pigment dorsally on the disc edge. **525**

148. Chestnut, normal, 11 hour old foal. A yellow-green tapetal fundus showing uneven pigmentation in the dorsal part. The small dark dots are Stars of Winslow. **526**

149. Adult, bay horse. This view shows a typical pale optic disc and retinal vessel pattern. To one side of the disc there is a large discrete area of partial loss of pigment (appears pink) immediately next to the border. Retinal vessels are still seen running through it and it is almost certainly a type of atypical coloboma. It is surrounded by a more generalised, but less severe, area of non-tapetal fundus depigmentation allowing choroidal and vortex veins to be distinguished as red-purple striations or dense spots. **527**

150. Bay, normal, 59 hour old foal. This peripapillary fundic view shows a normal-shaped, salmon-pink, optic disc with light centre and dorsally, a thin light border. There is a small mid-ventral white rim and one tortuous retinal vessel on the disc. Dorsally, there is slight depigmentation of the non-tapetal fundus with a thin rim of pigment clumping adjacent to the disc dorso-nasally. 528

151. Grey, normal, 16½ hour old foal. This pink, nasally blunted, oval optic disc, has a mid-ventral white rim, light border and centre, and slight dorsal extension. The dorsal-to-disc area of the grey brown non-tapetal fundus is partially depigmented, with choroidal vessels visible and increased pigment deposits adjacent to the dorsal disc margin. 529

152. Bay, normal, 20 hour old foal. The view of the peripapillary region reveals a pale pink, normal optic disc with a light centre and border, and slightly irregular dorsal edge. There is one particularly prominent and tortuous retinal vessel running from well within the disc onto the non-tapetal fundus. 530

153. A dark grey, normal, neonatal foal. The mottled bluish-green dorsal tapetal fundus with prominent Stars of Winslow are seen in this restricted view. 531

154. Chestnut, normal, 15 hour old foal. This view of the fundus shows the yellow-green tapetal and dark grey-brown non-tapetal parts, separated by a distinct straight border. The Stars of Winslow are easily seen in the tapetal fundus. 532

155. Bay, normal, 31 hour old foal. Right eye. Salmon-pink, optic disc with dorsal bulge and dorsal-to-disc depigmentation. Within this area are just visible reddish-purple parts of choroidal vessels. Note the straight, distinct border between tapetal and non-tapetal fundus. 533

156. Bay, normal, 60 hour old foal. This is a view of the non-tapetal fundus ventro-nasal to the optic disc. Note the ragged border and dark brown non-tapetal fundus. **534**

157. Bay, normal, 28 hour old foal. A slightly smaller and rounder pink optic disc with light centre, with obvious retinal vessel pattern, especially in the area of depigmentation dorsal to the disc. Note also how the border between the two parts of the fundus almost disappears dorsal to the disc. **535**

158. Bay, normal, neonatal foal. The temporal quadrant green-yellow tapetal fundus, which almost has a bluish tinge, is seen just dorsal to a distinct border with a dark, almost black non-tapetal fundus. Note the focal, slightly darker, areas of tapetal colouration scattered through the tapetal fundus which Latimer *et al* (1983) describes as tapetal islands. **536**

159. Bay, normal, 6½ hour old foal. This peripapillary view of the left eye shows a pink to red-pink, normal-shaped optic disc which is very nearly homogenous, but with a slightly light centre. The dark brown non-tapetal fundus is very mildly depigmented dorsal to the disc, with a number of prominent red choroidal vessels in this area. Small splash and punctate retinal haemorrhages are seen dorsal to the disc in the yellow-green tapetal fundus. **537**

160. Bay, normal, 60 hour old foal. This view of the peripapillary fundus shows a pink optic disc with light centre and border, and an irregular, almost triangular shape. The dorsal part of the disc shows a bulge which may be increased myelination. Dorsal to the disc there is loss of pigmentation of the non-tapetal fundus, with small areas of pigment clumping immediately adjacent to the dorso-nasal and ventral disc margin. Underlying choroidal vessels are just visible. To the dorso-nasal side of the disc are small areas of irregular depigmentation, possibly of a tapetal fundus colour. These may be tapetal islands as described by Latimer *et al* (1983). The tapetal fundus is yellow-green and shows prominent Stars of Winslow, especially peripherally. 538

161. Chestnut, normal, 15 hour old foal. This salmon-pink, slightly rounded optic disc has a light centre and dorsal border. The dorsal-to-disc area is depigmented with peripapillary pigment clumping. 539

162. Bay, normal, 17 hour old foal. A pink, light centre and border, nasally blunted and larger than normal disc is seen in a dark grey-brown non-tapetal and yellow-green tapetal fundus. There is slight dorsal extension of the disc, mild dorsal-to-disc depigmentation, a small number of localised red choroidal vessels and a straight normal border. The Stars of Winslow are quite difficult to identify. 540

163. Chestnut, normal, 15 minute old foal. A red-pink, almost red, homogenous optic disc with irregular edge. Ventrally there are several areas where the disc appears to extend outwards around the retinal vessels. 541

164. Bay, normal, 13 hour old foal. A red-pink optic disc is seen with a light centre and border, small mid-ventral white rim and dorsal extension of disc margin. The dorsal-to-disc non-tapetal fundus is depigmented with slight evidence of red choroidal vessels. Note the normal retinal vessel pattern. 542

165. Bay, normal. 11 hour old foal. A view of the peripapillary area of the fundus showing a yellow-green tapetal and dark grey-brown non-tapetal fundus, separated by a straight normal border. The normal shaped, nearly red-pink optic disc has an almost homogenous appearance with a slightly lighter border and centre. The dorsal-to-disc area has a mild loss of pigment with accompanying red choroidal vessels. The retinal vessels are normal. 543

166. Bay, normal,11 hour old foal. The right eye of this foal has a pink optic disc (compare figure 165 with red-pink disc) with a light centre and border. 544

167. Dark grey, normal, 10½ hour old foal. Left eye. A slightly nasally blunted, oval, red-pink optic disc contains a single, large, splash-like, fresh, retinal haemorrhage centrally. Also present is a mid-ventral white rim to the disc, slight dorsal-to-disc depigmentation, dark brown-grey non-tapetal fundus, and green tapetal fundus. 545

168. Dark brown. normal, 14 hour old foal. A pale pink, large round optic disc with slight extension on one edge is seen in this peripapillary view. Note the orange-pink "streak" of dorsal-to-disc depigmentation running from the disc equator dorsally. There is slight pigment accumulation around the disc margin. 546

169. Chestnut, normal, 18 hour old foal. This peripapillary view is of the opposite eye to figure 147 and shows a flattened oval optic disc, especially ventrally, with pink colouration and light centre and border. Note the prominent intra-disc tortuous vessel. 547

170. Bay, normal, 16 hour old foal. A peripapillary fundic view showing a nasally blunted, pale pink optic disc of normal size with a light centre and slight dorsal extension. There is mild dorsal-to-disc depigmentation and choroidal vessel appearance. 548

171. Bay, normal, 19½ hour old foal. This view shows a pale pink optic disc with a light centre and border and a flattened, almost notched, ventral border. 549

172. Chestnut, normal, 6 hour old foal. A pink, homogenous, normal shaped optic disc is seen at the edge of this view of the dark brown-grey non-tapetal fundus. The border, which was straight and normal, becomes more ragged as it approaches the disc, dorsal to which is an area of depigmentation. Within the non-tapetal fundus, just to the non disc side of the flash reflection, is a small, punctate, whitish, non-pigmented area, an atypical coloboma. The green-yellow tapetal fundus is just visible. 550

173. Grey, normal, 18 hour old foal. This view of the optic disc shows a mid ventral white rim, red-pink colouration, lighter centre and partial border, and enlarged retinal vessels ventro-temporally. This foal had retinal haemorrhages in the green-yellow tapetal fundus. 551

174. Dark grey, normal, 10½ hour old foal. Right eye. A slightly nasally blunted, oval, pink optic disc with mid-ventral white rim, light centre and slight dorsal extension, does not contain any haemorrhages in this eye. The retinal pigment epithelium depigmentation is more obvious in this eye, both dorsal to the optic disc and peripherally. 552

175. Bay, normal, 12 hour old foal. The normal shaped, red-pink optic disc with light centre and border has, on the temporal border and running into the non tapetal fundus, a number retinal blood vessels with increased tortuosity. 553

176. Bay, normal, 60 hour old foal. A peripapillary view of this foal showing the blue-green tapetal fundus and choroidal vessels, including a few purple spots representing end-on vessels. The lack of retinal vesels is clearly demonstrated. **554**

177. Bay, normal, 5 day old foal. Many widespread, mauve, resolving, mixed pattern retinal haemorrhages are seen in the green-blue tapetal fundus. Notice the way the centre of the haemorrhages are paler and the edges are diffuse and indistinct. The optic disc in this older foal is of a more normal adult colour and appearance (pale pink, light centre and border, mid-ventral white rim, normal oval shape), but on one edge, with careful examination, two streak haemorrhages immediately around two retinal vessels can just be seen. **555**

178. Chestnut, normal, 6 hour old foal. This peripapillary view shows a normal shaped, pink disc with slightly light centre. The retinal vessel pattern is very obvious in the dorsal-to-disc depigmented region of the non-tapetal fundus, as straight red lines radiating outwards just over one disc's diameter. Ventrally the disc appears to extend out along the line of the retinal vessels giving an almost "frilly" appearance. **556**

179. Grey, normal, 18 hour old foal. A view of the fundus of the left eye showing approximately 10 small splash retinal haemorrhages in the tapetal area. They are of a reddish-purple colour, show early resolution and, although widespread, are concentrated more temporally. Note the yellow tapetal fundus and dorsal pigment mottling, normal border region and dark brown non-tapetal fundus. **557**

180. Chestnut, normal, 59 hour old foal. The left eye of a foal showing the resolution of the dorsal-to-disc retinal haemorrhages (compare figure 193). The green-yellow tapetal fundus contains 4 mauve, resolving retinal haemorrhages with diffuse edges, making them more difficult to detect, in a discrete area dorsal to the optic disc. Note also the dorsal tapetal fundus dark brown mottling, the distinct border with the dark brown-grey non-tapetal fundus, and the area just dorsal to the optic disc which shows depigmentation and overall reddish-brown colouration. 558

181. Chestnut, normal, 2 day old foal. 2 punctate and 1 small splash, acute, red retinal haemorrhages are seen in the upper dorsal area above the optic disc in the tapetal fundus. Note also the predominantly yellow tapetal fundus with occasional green spots, and dark brown mottling of the dorsal area. 559

182. Bay, normal, neonatal foal. The green-yellow tapetal fundus in the nasal quadrant is bounded dorsally by a mottled edge of dark pigment, and ventrally by the distinct border with the dark grey-brown non-tapetal fundus. 560

183. Bay, Normal 60 hour old foal. This view shows the ragged border between the tapetal and non-tapetal fundus. There are obvious foci of depigmentation just below the border and for some considerable distance ventrally into the dark brown non-tapetal fundus. 561

184. Bay-brown, normal, 15 minute old foal. A dark brown-grey non-tapetal fundus is seen to one side of the optic disc. The border is slightly ragged and appears to dip towards the disc. The yellow-green tapetal fundus extends into the dorsal-to-disc area. 562

185. Dark brown, normal, 14 hour old foal. A small, ragged edge, white, atypical coloboma is seen at the border of the tapetal/non-tapetal fundus just temporal to the choroidal "streak" / dorsal-to-disc depigmented area. **563**

186. Bay, normal, 6½ hour old foal. This view of the right eye shows the nasal region of the border area with 6 early resolving, small, splash, red-purple retinal haemorrhages. These were part of a large number (>10) mixed, punctate and splash haemorrhages evident only on the nasal side of the tapetal fundus. The straight normal border, dark brown non-tapetal and yellow-green tapetal fundi, are also visible. **564**

187. Chestnut, normal, 18½ hour old foal. At the level of the ventral half of the disc and on its nasal side are 4 unpigmented, small, round areas, previously described as atypical colobomas. All are within one disc's diameter of the disc and have retinal vessels running through them. The dorsal and largest area has the whitest colour suggesting the greatest degree of depigmentation. **565**

188. Bay, normal 60 hour old foal. This fundic view shows marked peripapillary choroidal and retinal pigment epithelium degeneration with obvious choroidal vessels especially dorsal to the disc. The pale pink optic disc is of normal shape and size, with a light centre and border, and ragged dorsal extension. Retinal vessels are decreased in number, although a few thickened ones are present on the temporal equator. Two focal whitish lesions are present ventral and nasal to the disc in the non-tapetal fundus. Notice the overall greyish appearance of the non-tapetal fundus. **566**

189. Bay, normal, 1 day old foal. Multiple, punctate, small and large splash-like, acute retinal haemorrhages are widespread in the green-blue tapetal fundus of this foal. **567**

190. Bay, normal, 4 day old foal. Multiple, widespread, resolving, punctate retinal haemorrhages are seen in this green-yellow tapetal fundus particularly just dorsal to the border with the non-tapetal fundus. 568

191. Bay, normal, 6½ hour old foal. This view of the left eye (see figure 186) shows mixed punctate and large splash, red-purple, early resolving, retinal haemorrhages in the dorsal tapetal fundus where there is dark brown pigment mottling. These haemorrhages were part of a group of between 6 and 10 that were localised in an area dorsal to the disc. 569

192. Chestnut, normal, 11 hour old foal. A single, small, splash-like retinal haemorrhage is present dorsal to the disc in the right eye. It is already purplish and in the early stages of resolution. The retinal vessel pattern is especially obvious dorsal to the disc. 570

193. Chestnut, normal, 11 hour old foal. A ragged border is present between the green-yellow tapetal and dark grey-brown non-tapetal fundus. Some of the widespread retinal haemorrhages (between 15-20 in total) are present in the tapetal fundus of the left eye. These are reddish-purple and of a mixed pattern, including one large splash type. 571

194. Bay, normal, 6½ hour old foal. This overexposed view shows the nasal region of the fundus of the right eye, and the large number of mixed punctate and splash retinal haemorrhages throughout the tapetal area. 572

195. Chestnut, normal, 59 hour old foal. The right eye of a foal with widespread, mixed pattern, resolving retinal haemorrhages (compare figure 193). This limited view of the tapetal fundus just above the border shows decreased numbers of haemorrhageswith more diffuse edges. Those visible appear larger, are now mauve, and are more difficult to detect (see also left eye figure 180). 573

196. Gross specimen of normal posterior segment of adult equine eye. The section is cut transversely just behind the lens. The grey mist-like appearance over the fundus is the partially detached retina. Note the pink, irregular oval optic disc situated just below the border between the green tapetal and dark brown non-tapetal fundi. The dorsal and peripheral pigment mottling in the tapetal fundus is obvious. (section courtesy of J. Mould). 574

197. Chestnut, normal, 11 hour old foal. A ragged border between the green-yellow tapetal and dark grey-brown non-tapetal fundus is clearly seen. Note some of the widespread retinal haemorrhages present in the tapetal fundus (see figure 193). 575

198. Adult bay horse. These red-purple spots over the green-blue tapetal fundus are end-on choroidal vessels and should not be confused with retinal haemorrhages when seen in neonatal foals. 576

199. Adult bay horse. The vortex vein striations are clearly seen in the grey-brown non-tapetal fundus. 577

200. Adult riding pony with a history of a sudden onset of bilateral blindness following a fall and head trauma. Note the very pale optic disc, almost complete lack of retinal vessels and peripapillary/diffuse choroidal and RPE degeneration. 578

201. Heterochromia iridis is seen in this palomino pony. Notice the variation in colour as the iris approaches the pupillary margin. The pupil is a typical adult shape and size in ambient light. **579**

LIST OF APPENDICES.

1. A general external inspection of the head and ocular region was undertaken and, where necessary, palpation was used. Signs of ocular pain and discharge were of particular interest.

2. The response of foals to a threatening gesture with a hand was used to test the Menace reflex.

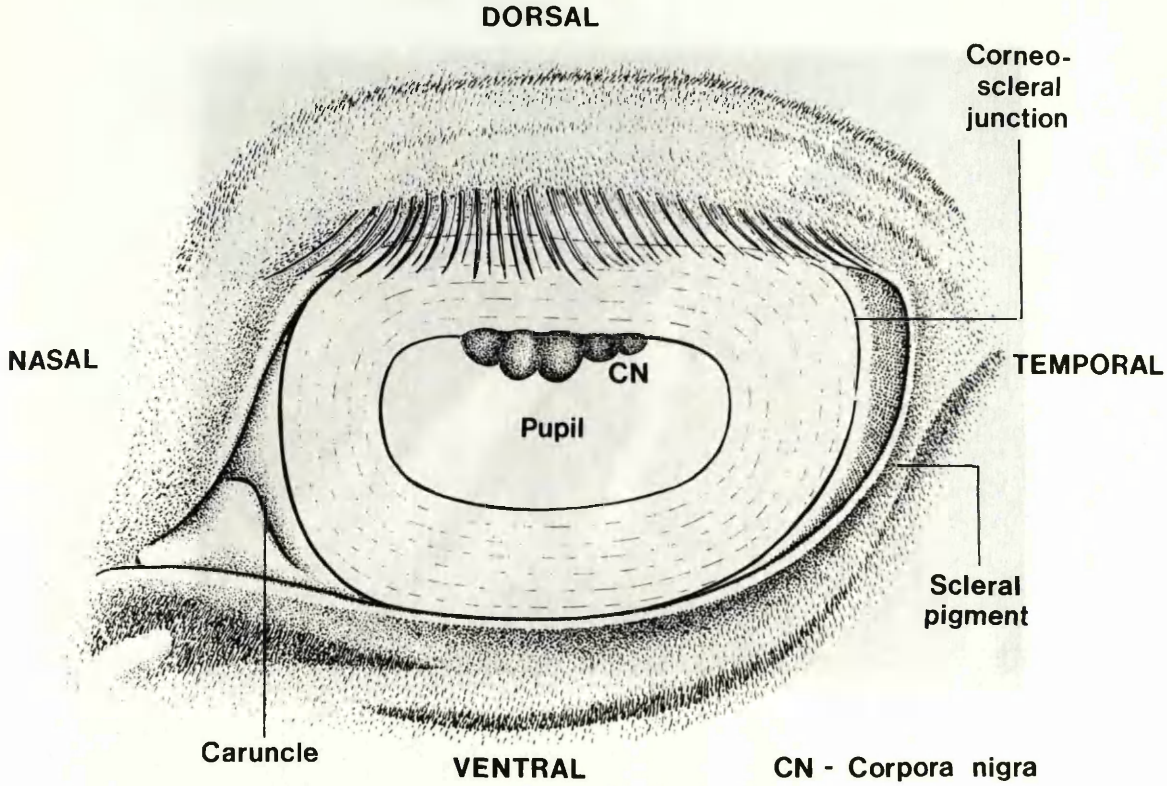
3. Examination of the external eye and anterior segment was conducted using a focused bright light from a pentorch (Keeler, London).

4. Examination of the external eye and anterior segment was also conducted, when required, using an otoscope (canula removed) (Keeler, London).

5. The blink response was tested by gentle touching of the canthi of both eyes.

6. An example of the use of a fluorescein dye test in an adult with diffuse superficial keratitis and corneal vascularisation. Single-use disposable ampoules of dye (fluorescein sodium B.P. 1% Minims, Smith and Nephew) were instilled into the lower conjunctival sac and, after one minute, the free solution lavaged from the eye using artificial tears (Minims, Smith and Nephew).

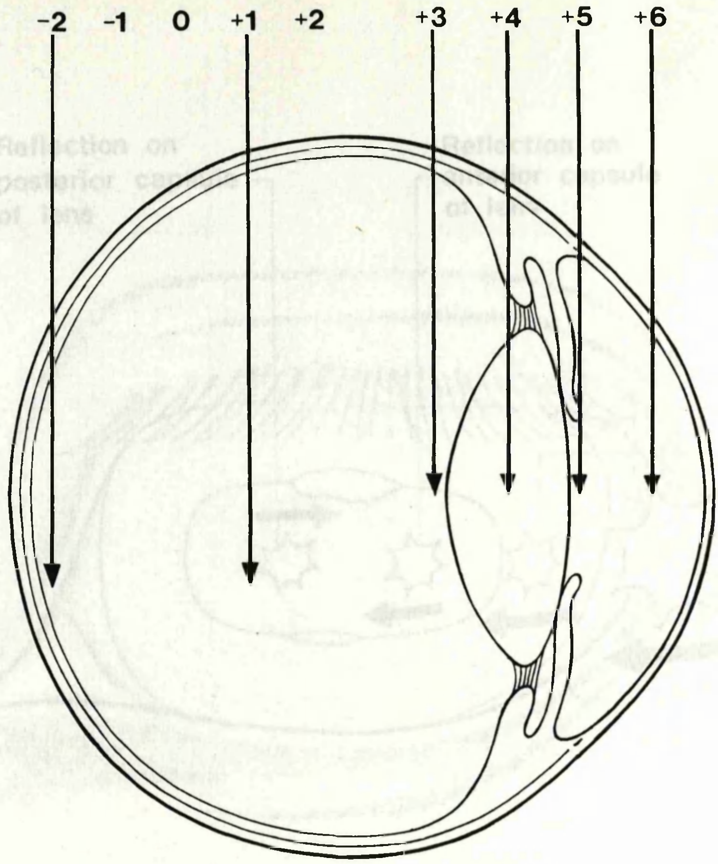
7. A corneal scraping being taken from the eye of a dog.



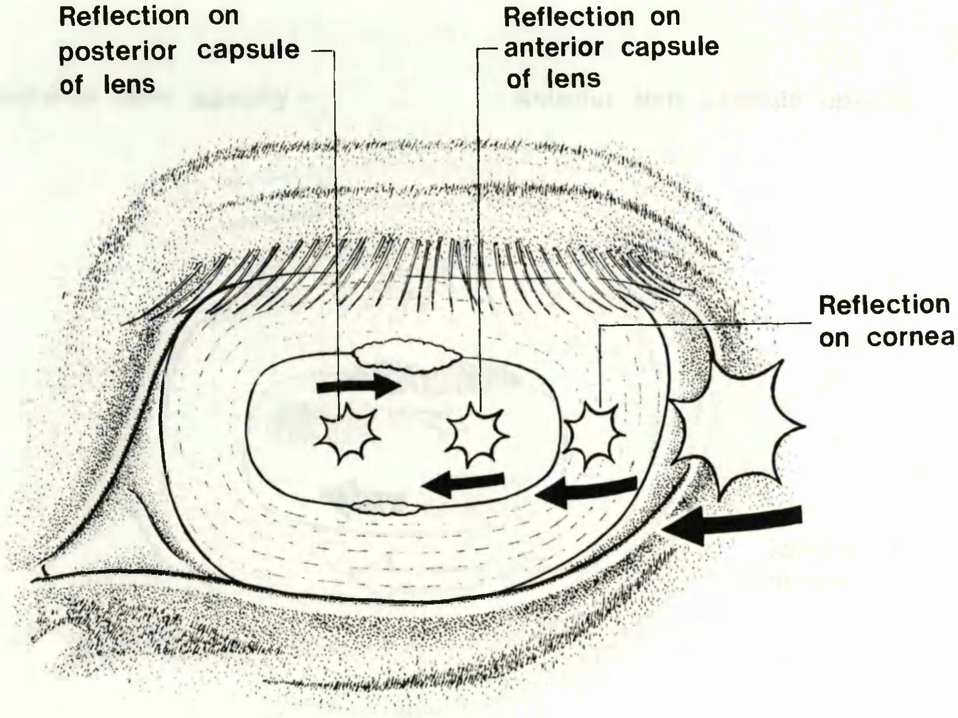
8. The recorded positions of scleral (subconjunctival) haemorrhages is shown in this diagram of the anterior aspect of the equine eye.

9. The use of a Keeler Practitioner ophthalmoscope for close direct ophthalmoscopy.

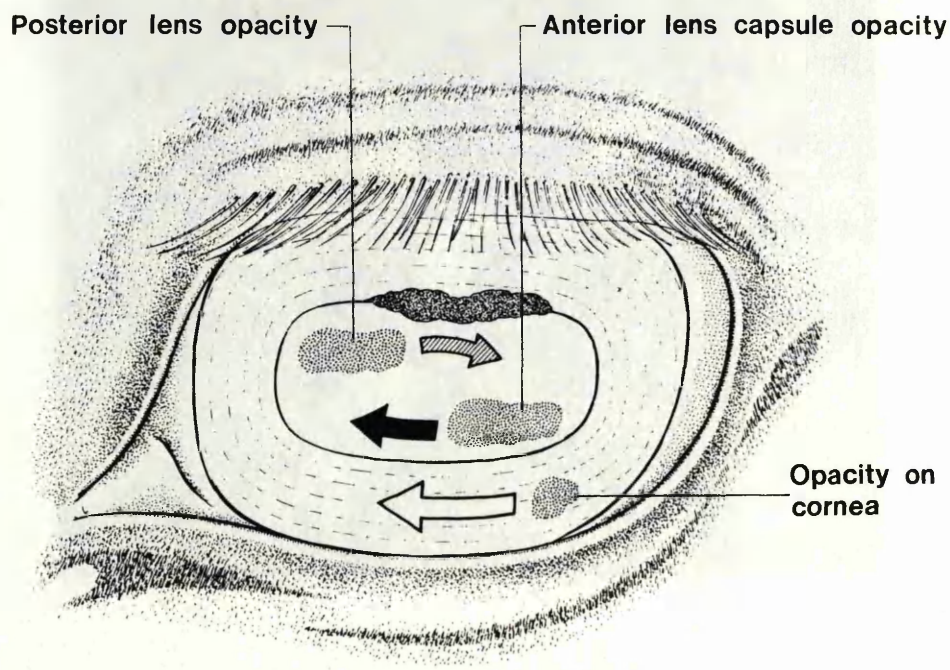
10. The use of a Keeler Practitioner ophthalmoscope for distant direct ophthalmoscopy.



11. Ophthalmoscope lens diopter settings used to view structures of the neonatal foal's eye at different depths in the eye (after Parker, 1983).

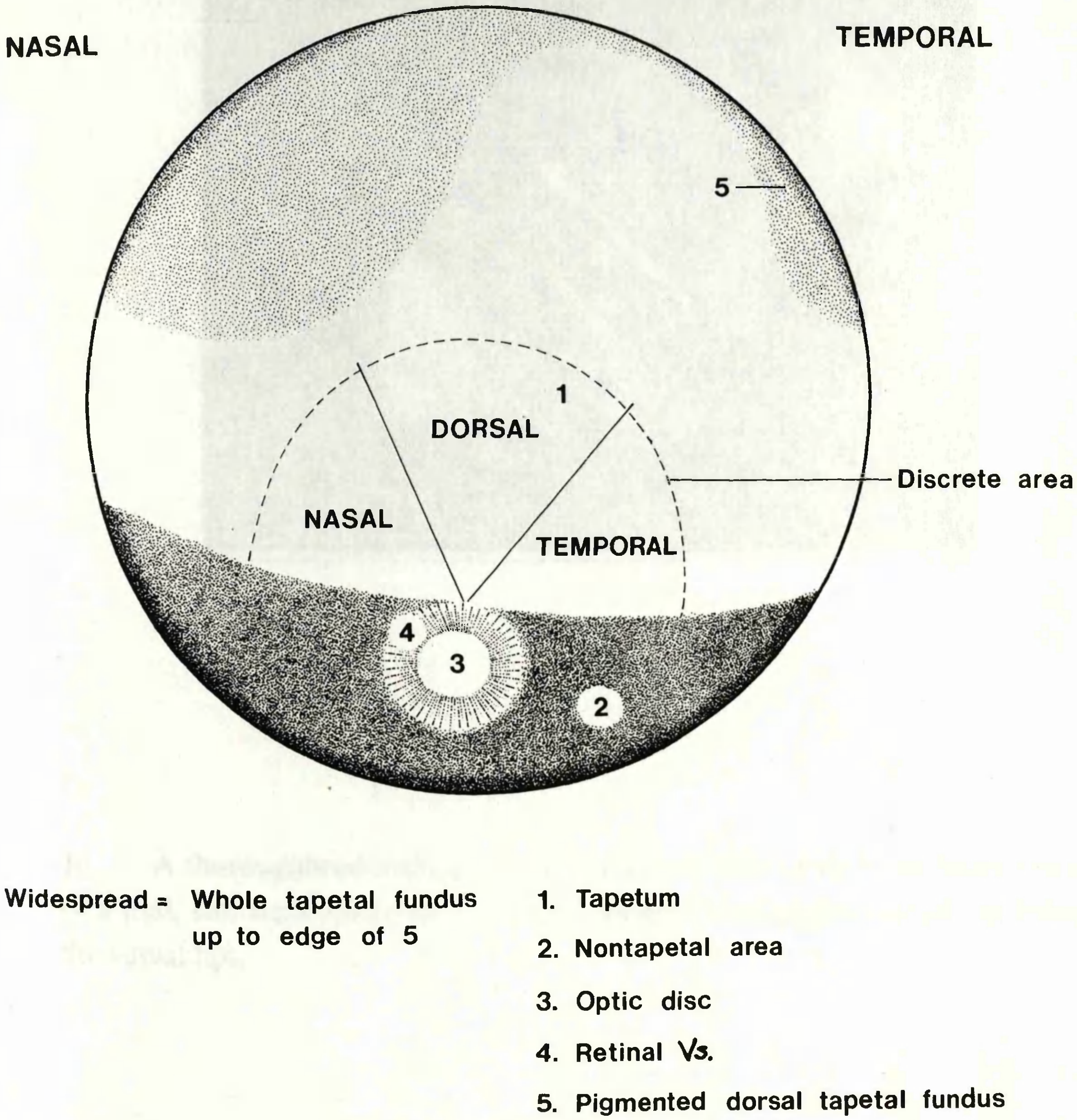


12. A diagram showing how Sanson-Purkinje images can be used to estimate the location of a lesion (after Lavach, 1990).



13. Localisation of an opacity in the equine eye using the Parallax technique. When the eye moves nasally, a corneal or anterior lens opacity moves in the same direction, whilst a posterior lens capsular lesion moves a little and a vitreal opacity temporally (after Blogg, 1985).

14. A portable Kowa SL-5 slit-lamp biomicroscope being used to examine a horses' eye.

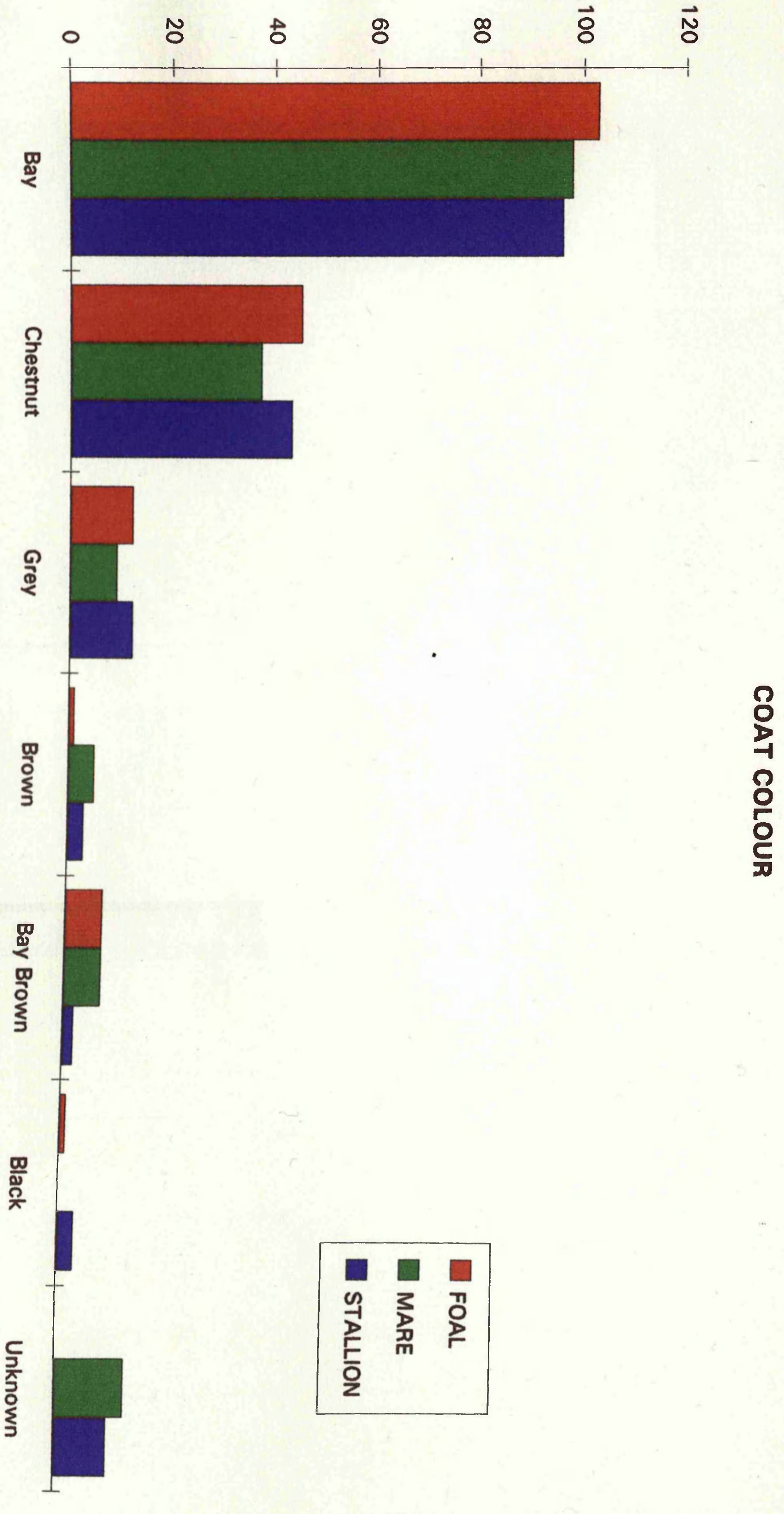


15. Diagram showing the retinal haemorrhage distribution areas in the tapetal fundus and optic disc.

16. A thoroughbred mare in second stage parturition with the head and legs of a foal, still surrounded by foetal membranes, having just passed out through the vulval lips.

17. The Kowa RC 2 fundic camera was used to obtain photographs of the anterior and posterior segments of the foals' eyes.

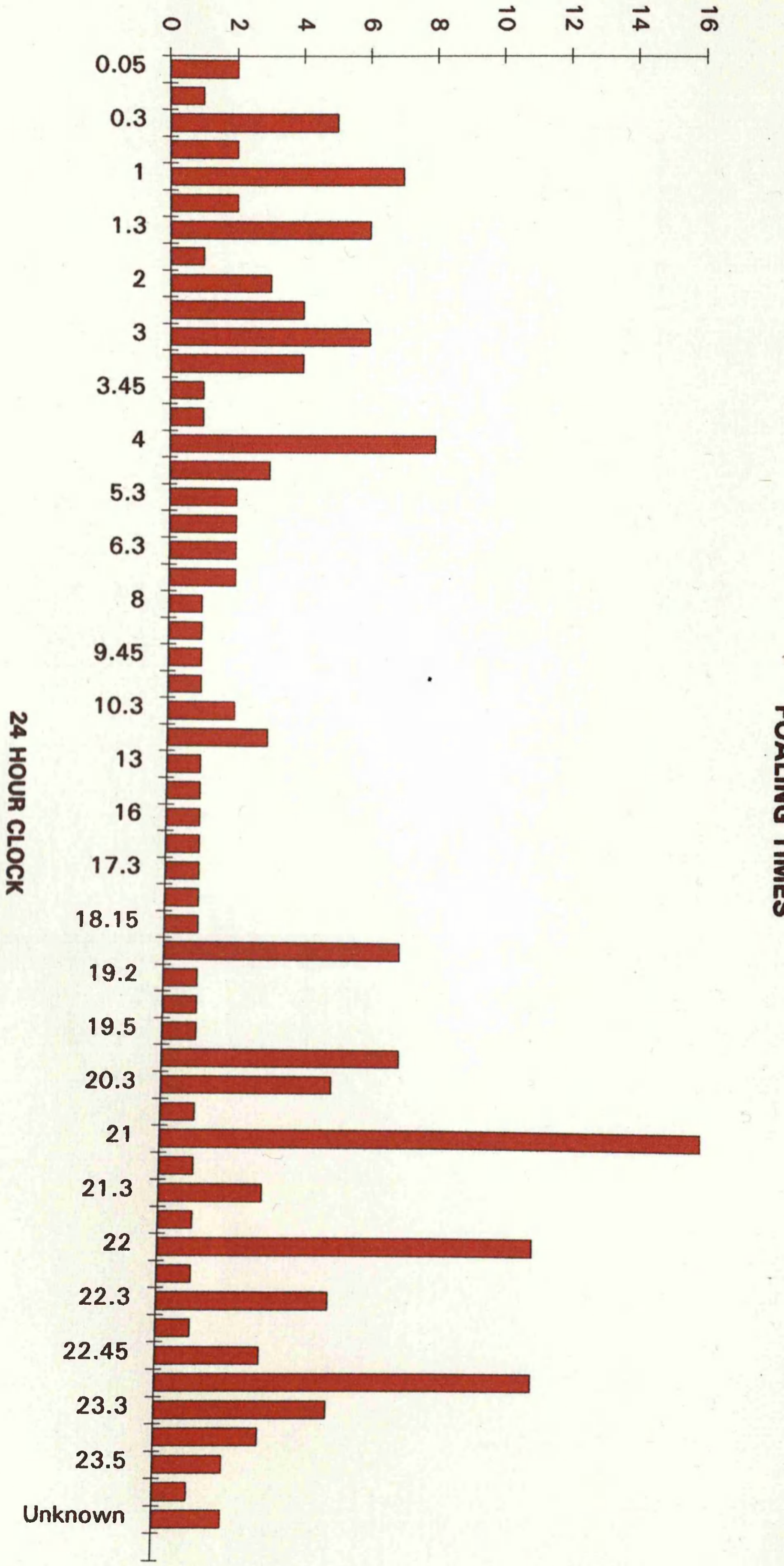
18. A single lens reflex (SLR) camera with automatic connecting tubes (Yashika FX3, Japan) was used to obtain some external eye photographs.



COAT COLOUR
FOAL
MARE
STALLION
0
20
40
60
80
100
120
Bay
Chestnut
Grey
Brown
Bay Brown
Black
Unknown

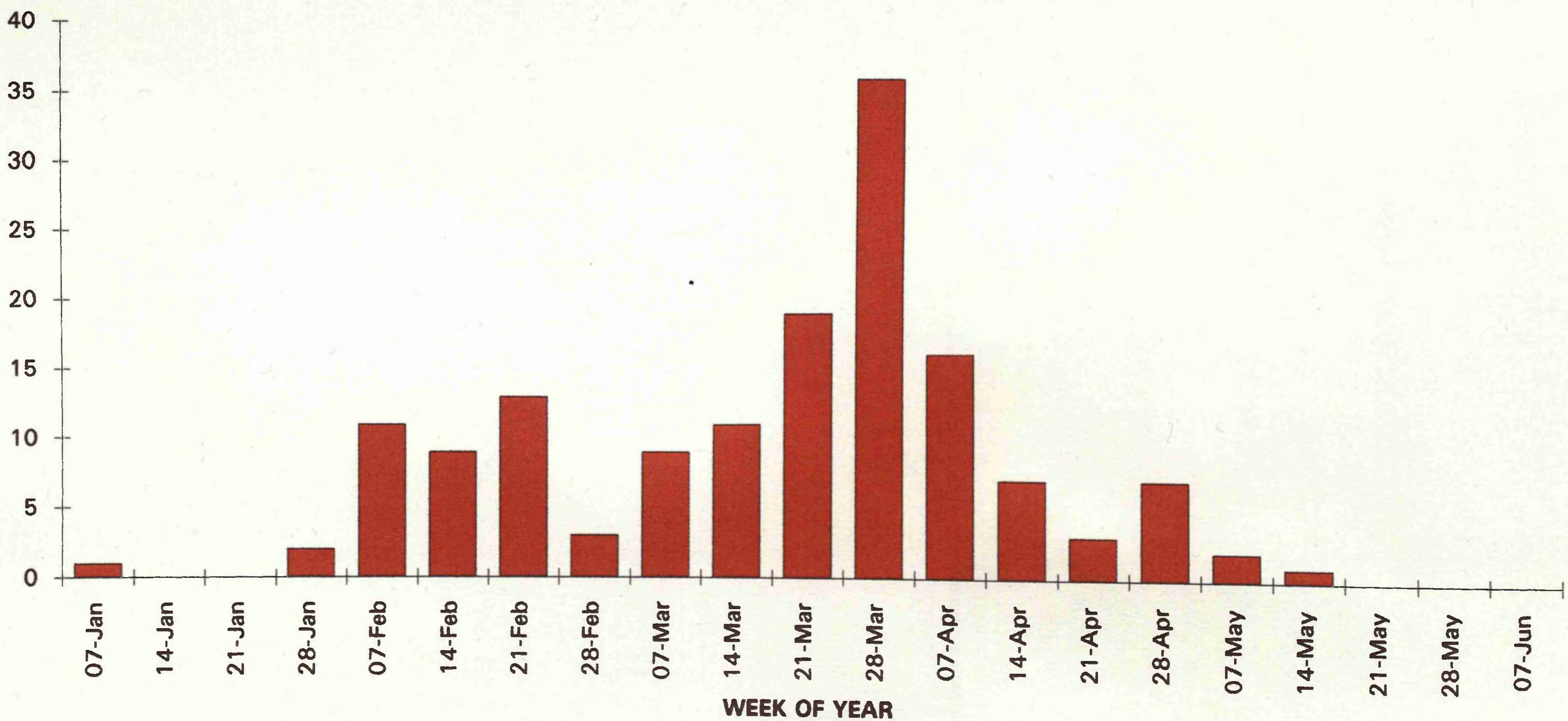
19. A graph showing the numbers of different coat colours in the foals and their parents.

20. The allantochorion part of the placenta laid out for examination after removal from the mare. The uterine surface shows a distinct demarcation between the dark red, normal area and the lighter, thickened abnormal part. The latter is covered in exudate and is typical of a placentitis.

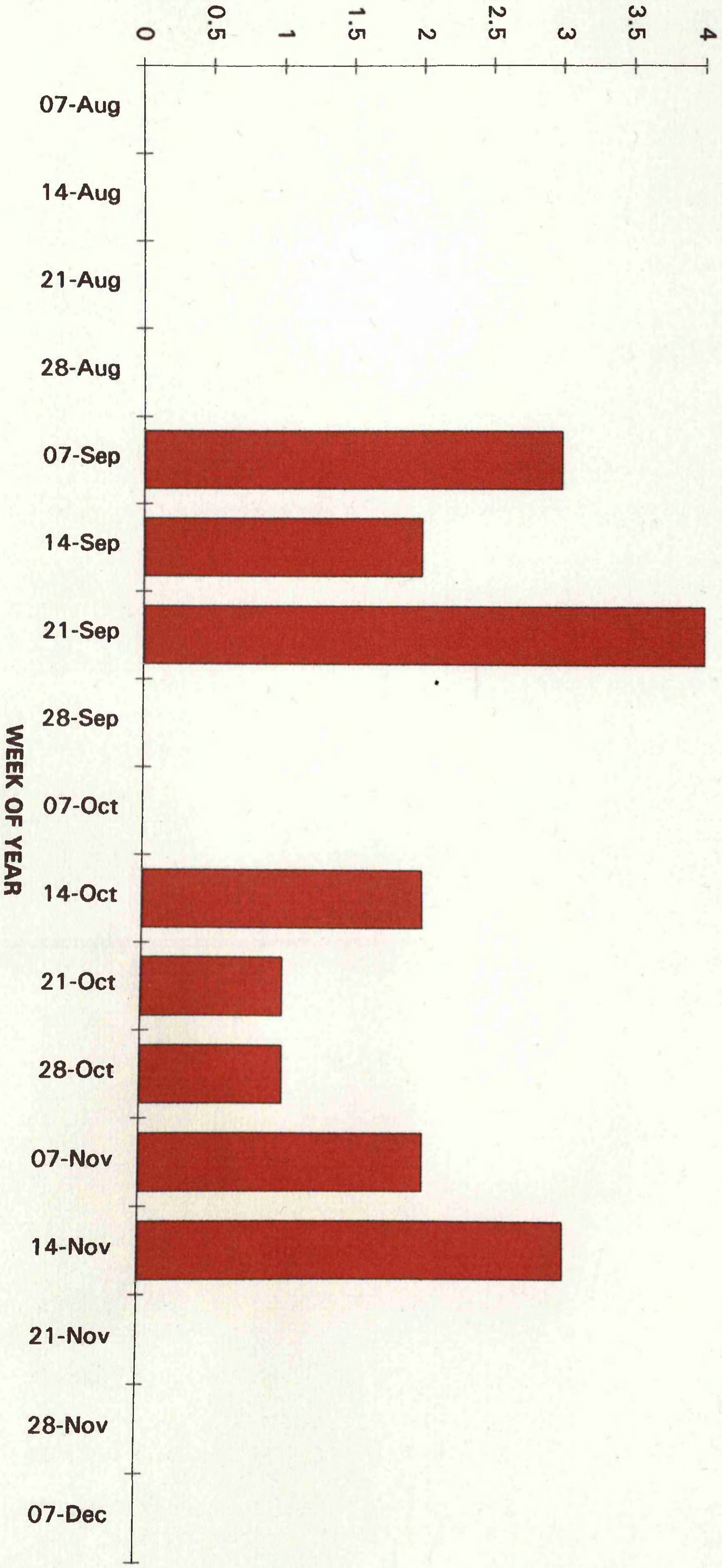

FOALING TIMES
24 HOUR CLOCK
0
2
4
6
8
10
12
14
16
0.05
0.3
1
1.3
2
3
3.45
4
5.3
6.3
8
9.45
10.3
13
16
17.3
18.15
19.2
19.5
20.3
21
21.3
22
22.3
22.45
23.3
23.5
Unknown

21. A graph showing the foaling times of the foals in this survey plotted against a 24 hour clock baseline.

TIME OF YEAR FOR U.K. FOALING

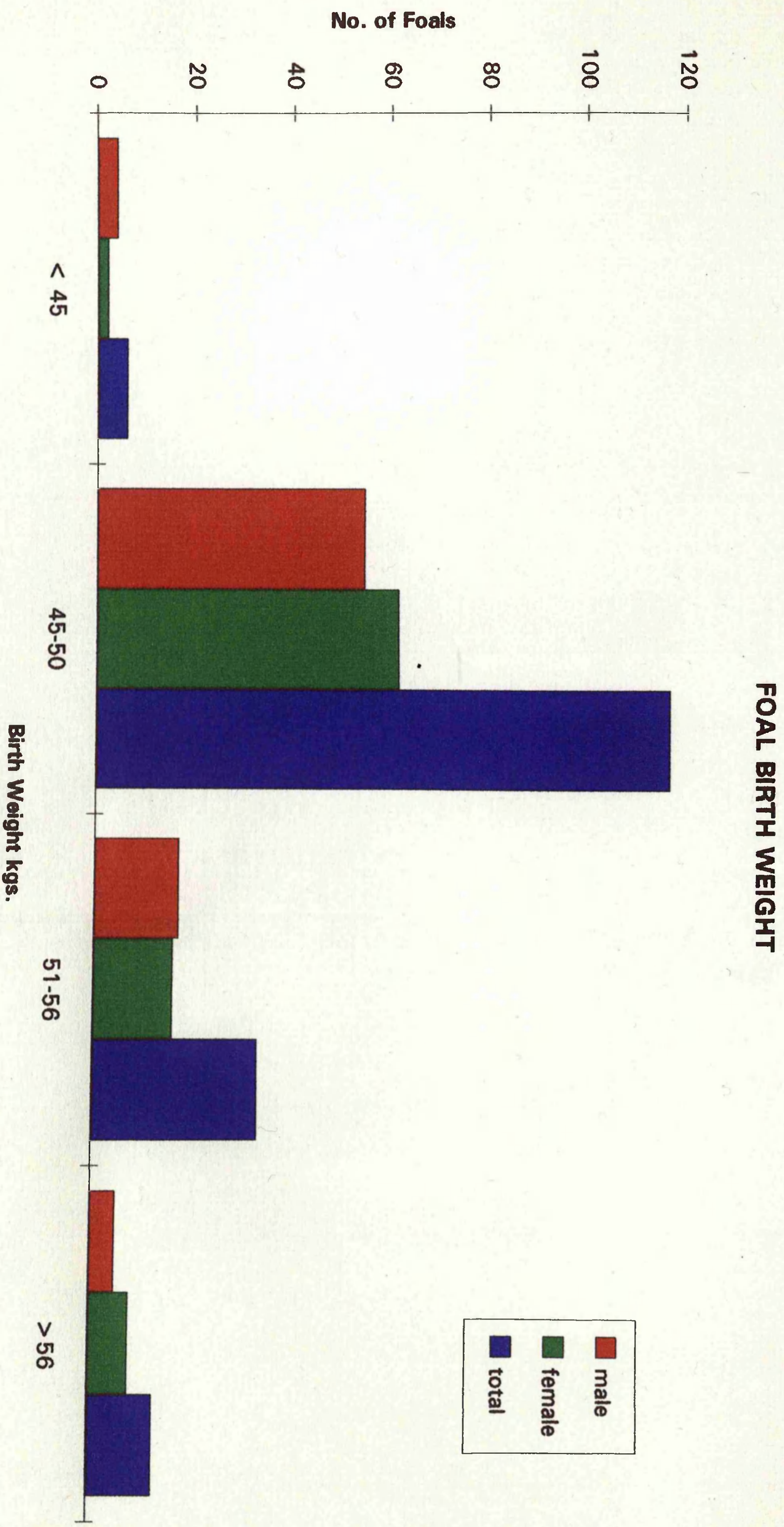


22. A bar graph illustrating the time of year of foaling in the U.K. for foals in this survey.



TIME OF YEAR N.Z. FOALING

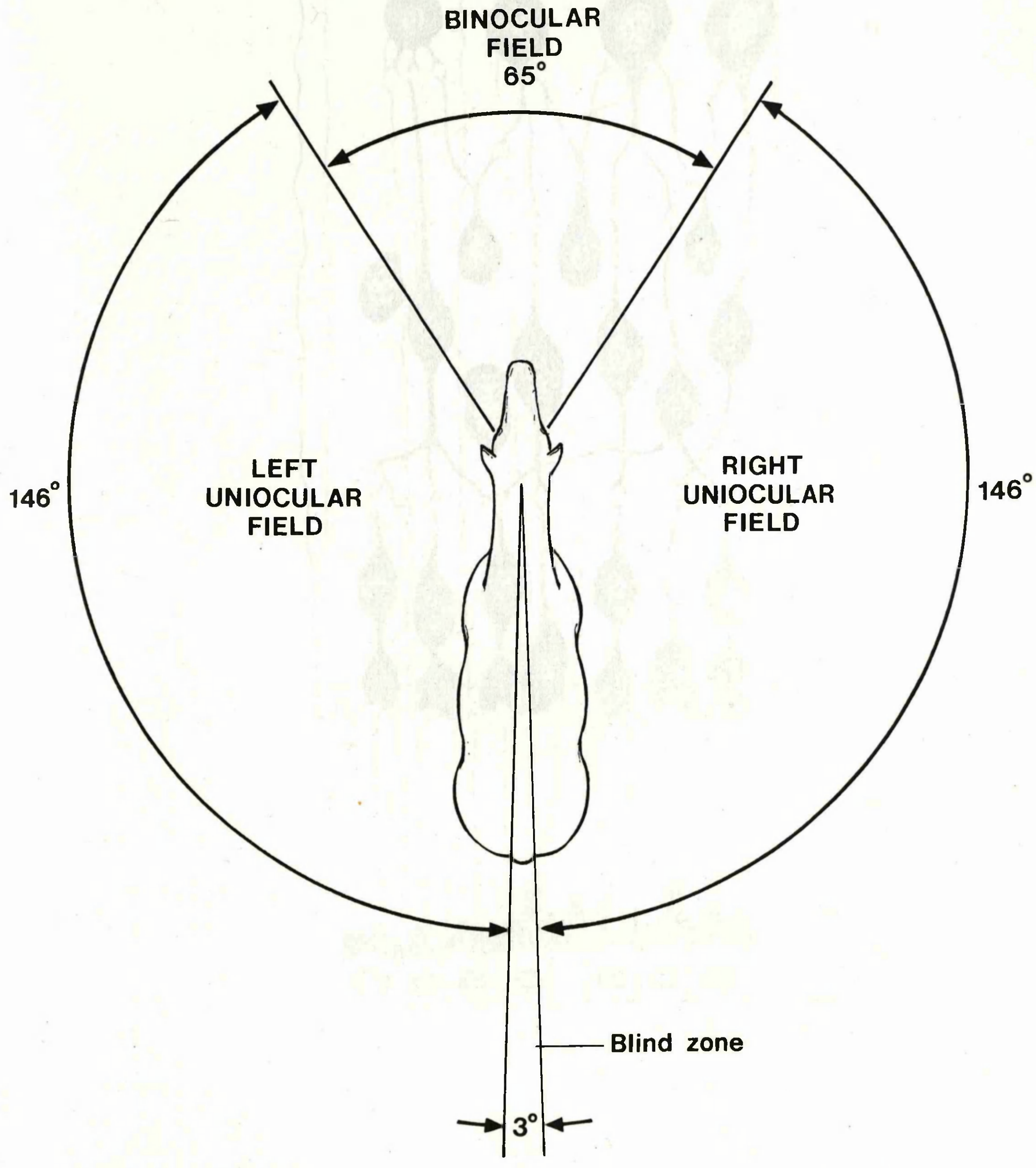
23. A bar graph illustrating the time of year of foaling in New Zealand for foals in this survey.


FOAL BIRTH WEIGHT
No. of Foals
0
20
40
60
80
100
120
< 45
45-50
51-56
>56
Birth Weight kgs.
male
female
total

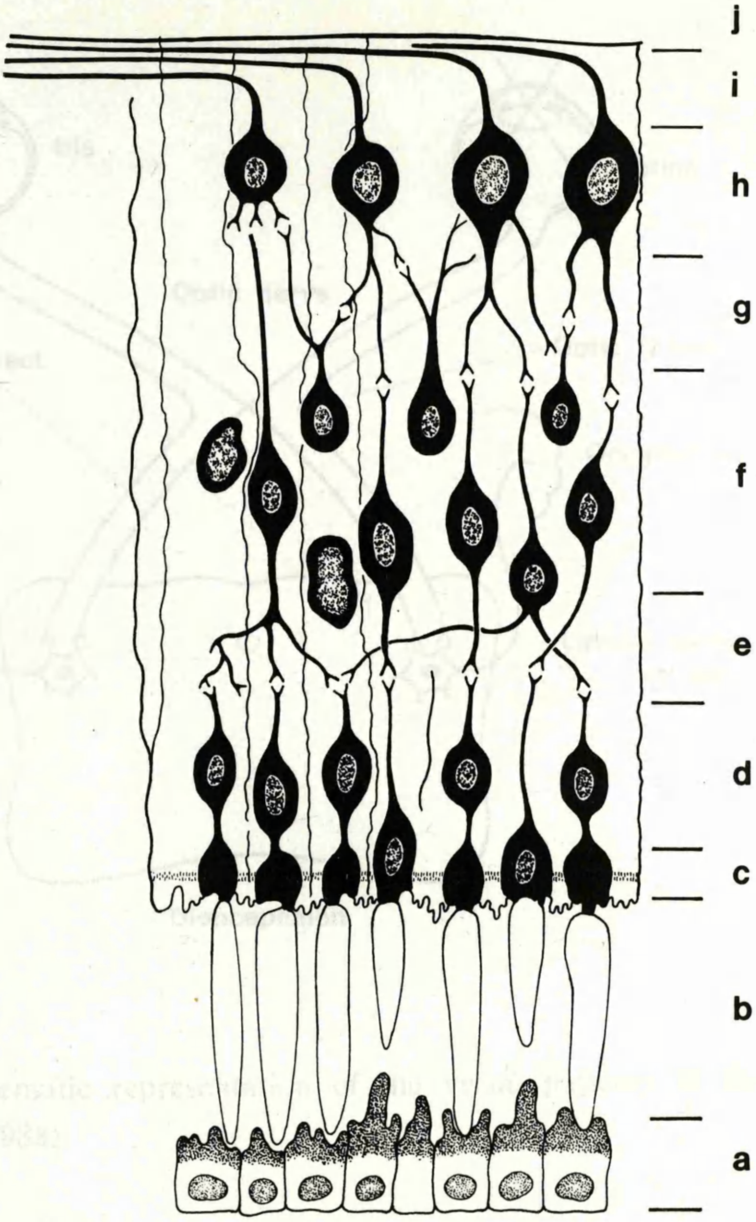
24. A bar graph illustrating the male and female foal birth weight in this survey.

25. A dysmature neonatal foal showing typical signs of low birth weight, weakness, short staring coat, fore and hind limb laxity and cuboidal bone hypoplasia in the carpal joints.

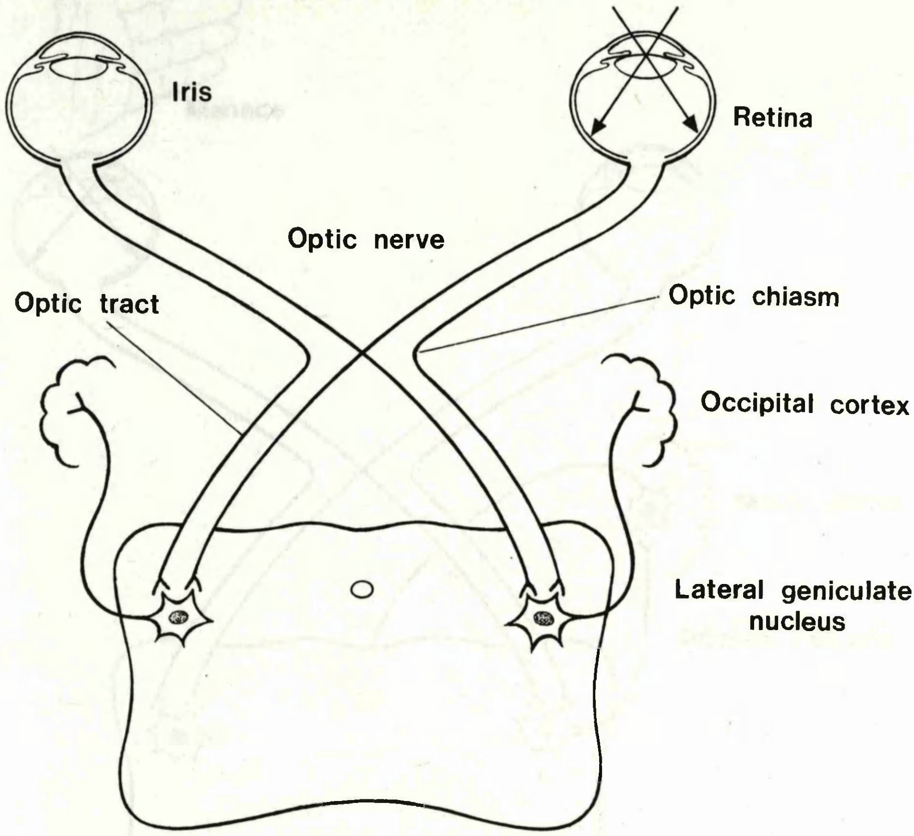
26. Chestnut neonatal foal (<24 hours old) with bilateral forelimb flexor deformity present at birth. This foal had a bilateral entropion (see figure 60).



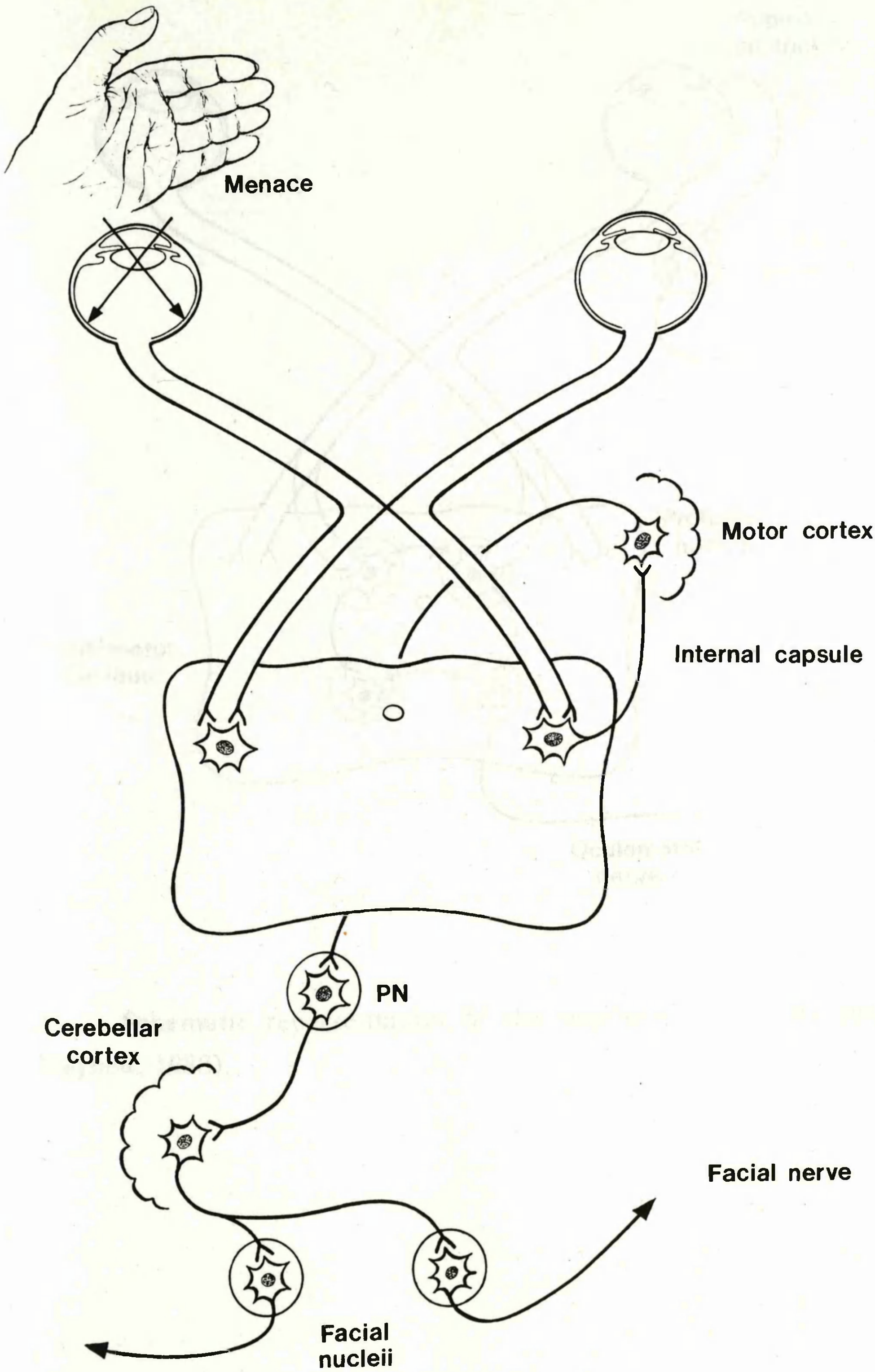
27. The visual field of the horse (after Blogg, 1985).



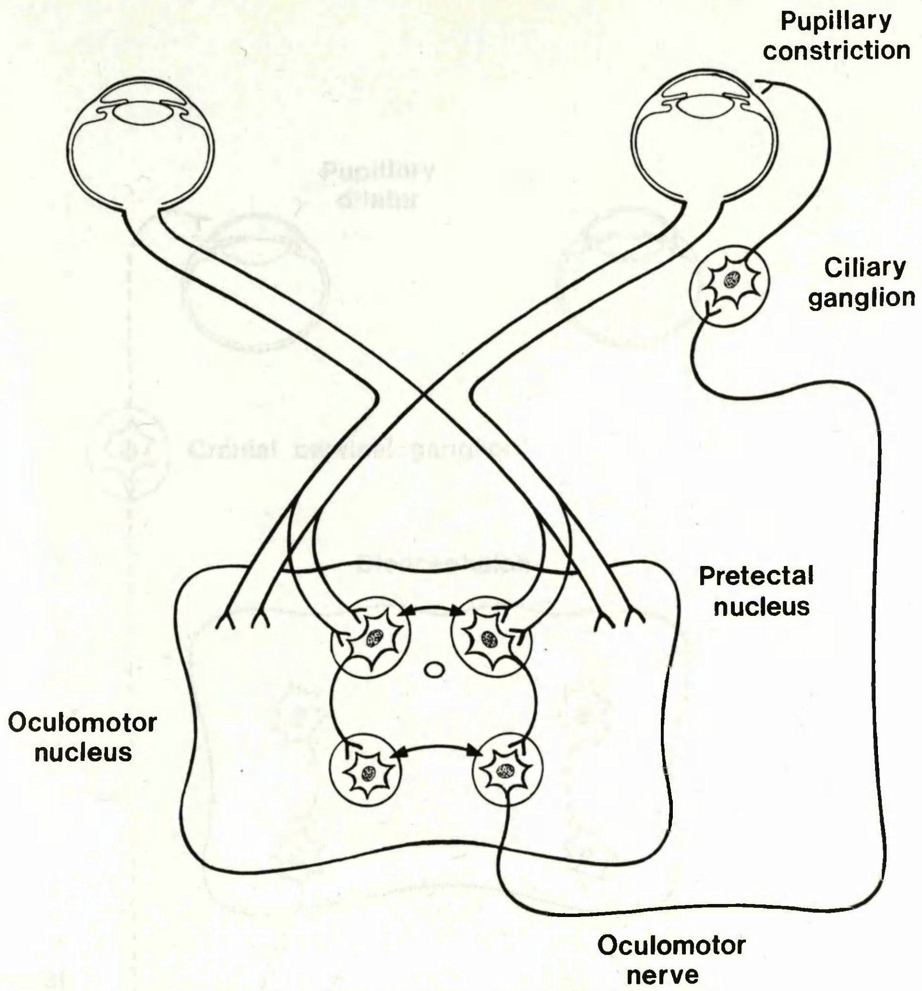
28. The structure of the equine retina in schematic form (after Lavach, 1990): a) Retinal pigment epithelium; b) photoreceptors (rods and cones); c) external limiting membrane; d) outer nuclear layer; e) outer plexiform layer; f) inner nuclear layer; g) inner plexiform layer; h) ganglion cell layer; i) nerve fibre layer; j) inner limiting membrane. See figures 143, 144 and 145.



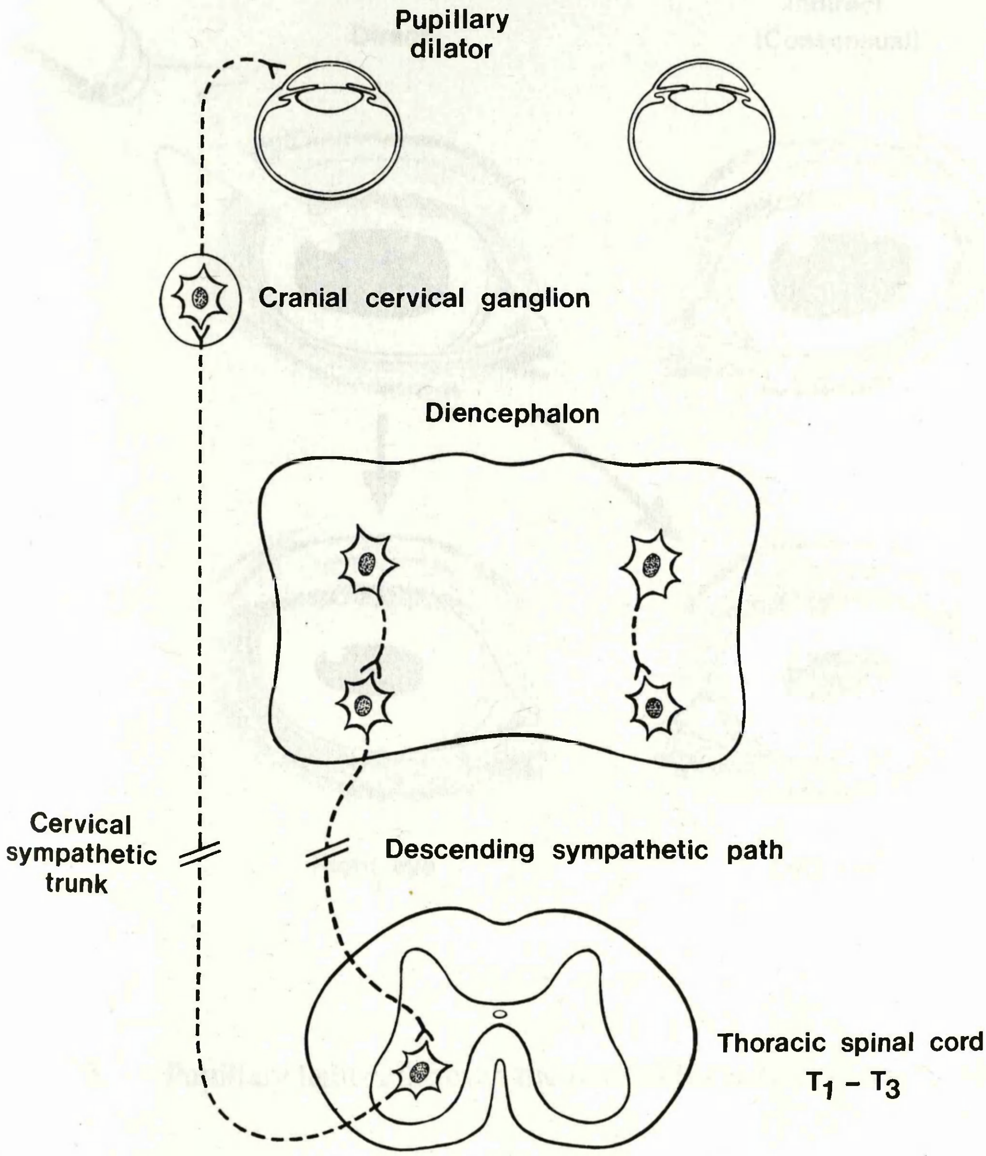
29. Schematic representation of the visual pathway in the horse (after Mayhew, 1988).



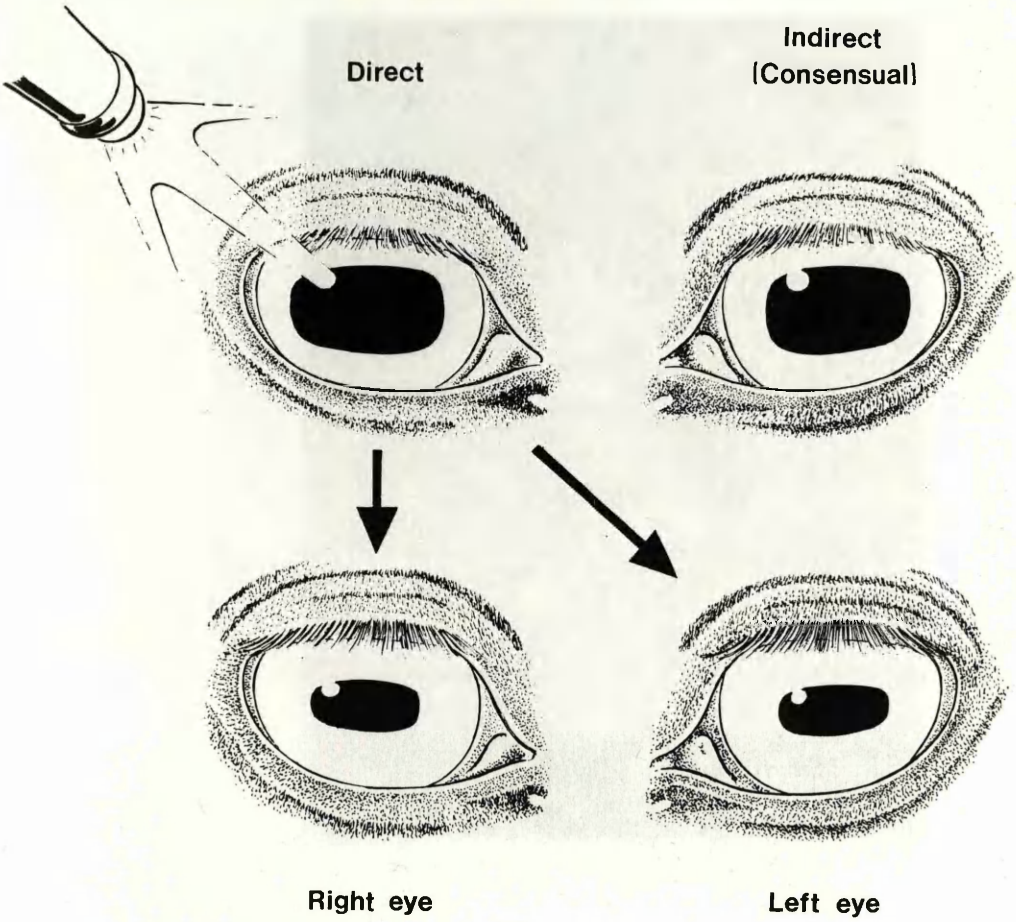
30. Schematic representation of the central pathways involved in the menace reflex (after Petersen Jones, 1989).



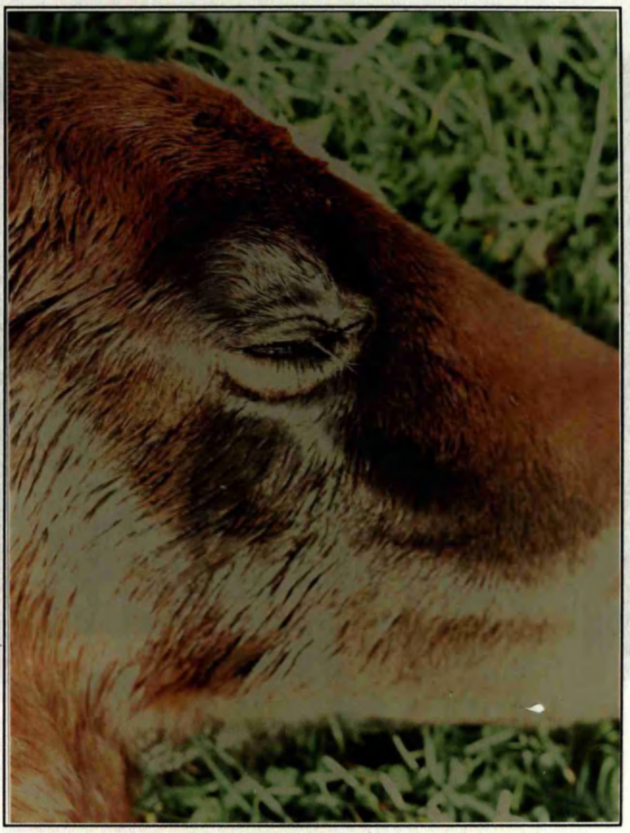
31. Schematic representation of the pupillary light reflex pathway (after Mayhew, 1988).



32. Schematic representation of the sympathetic pupillary pathway.



33. Pupillary light reflexes in the normal horse (after Lavach, 1990).



34. Bay, abnormal foal with septicaemia, 72 hours old. The right eye of this foal is shown immediately after the lower eyelid has been manipulated into a normal resting position. Both eyelids, which had secondary entropion, were treated similarly on a regular basis by the stud groom. Note the excessive lower eyelid fold and orbital sulcus, with wetting of the face due to excessive lacrimation and ocular discharge.

35. Bay, abnormal foal with septicaemia, 6 days old. See figure 34. The resolving, secondary entropion of the right eye is retracted ventrally to reveal the green-yellow hypopyon up to the level of the ventral pupillary margin. The globe is already soft and smaller than normal. Note the lower vibrissae.

36. Bay, abnormal foal with septicaemia. Post Mortem examination of the right hip joint after euthanasia at 14 days old. Note the severe damage to the articular cartilage of the femoral head due to the septic arthritis/osteomyelitis secondary to the neonatal septicaemia.

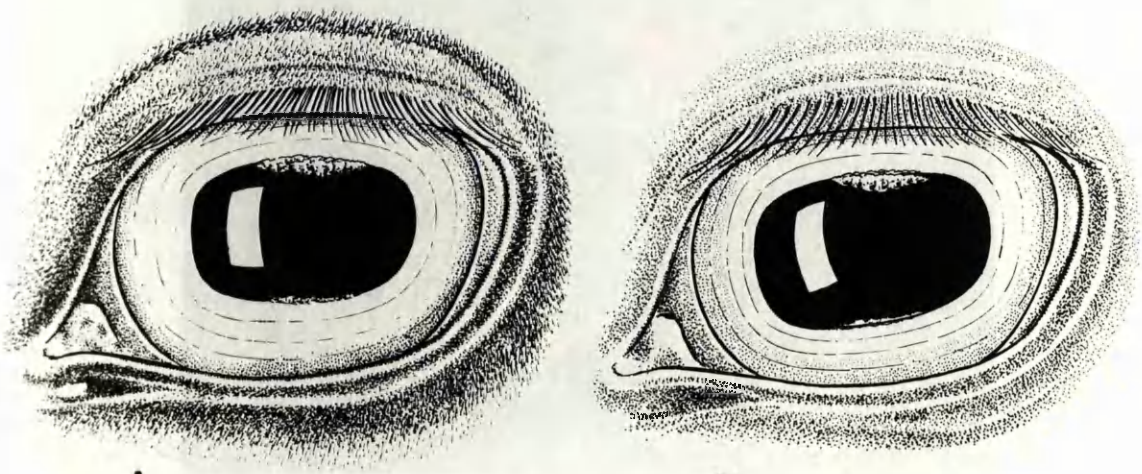
37a. Chestnut, abnormal, 12-24 hour old foal. This NMS foal suffered from severe self-inflicted trauma, including around both eyes. This figure shows the left external eye with severe excoriation of the eyelids, swelling and inflammation. The globe was withdrawn and a manually resolvable, secondary entropion was present.

37b. Chestnut, abnormal, 12-24 hour old foal. This NMS foal suffered from severe self-inflicted trauma, including around both eyes. This figure shows the right external eye with only mild excoriation on the lower eyelid.

38. Chestnut, abnormal, 12-24 hour old foal. This view of the left eye clearly shows the extreme chemosis, hyperaemia and inflammation of the upper and lower palpebral conjunctivae. The diffuse and mild corneal oedema is also visible, with a thread of antibiotic ophthalmic ointment on the lower eyelid margin.

39. Chestnut, abnormal, 12-24 hour old foal. This view of the right eye shows the acute anterior uveitis with grey-yellow swollen iris and miotic pupil covered by fibrin and a large haemorrhagic clot.

40. The dam of one of the foals in the survey showing a left eye microphthalmia of moderate degree, with enophthalmos, blindness, a small shrunken globe, and passively prolapsed nictitans. The right eye, and both eyes of its progeny were normal.



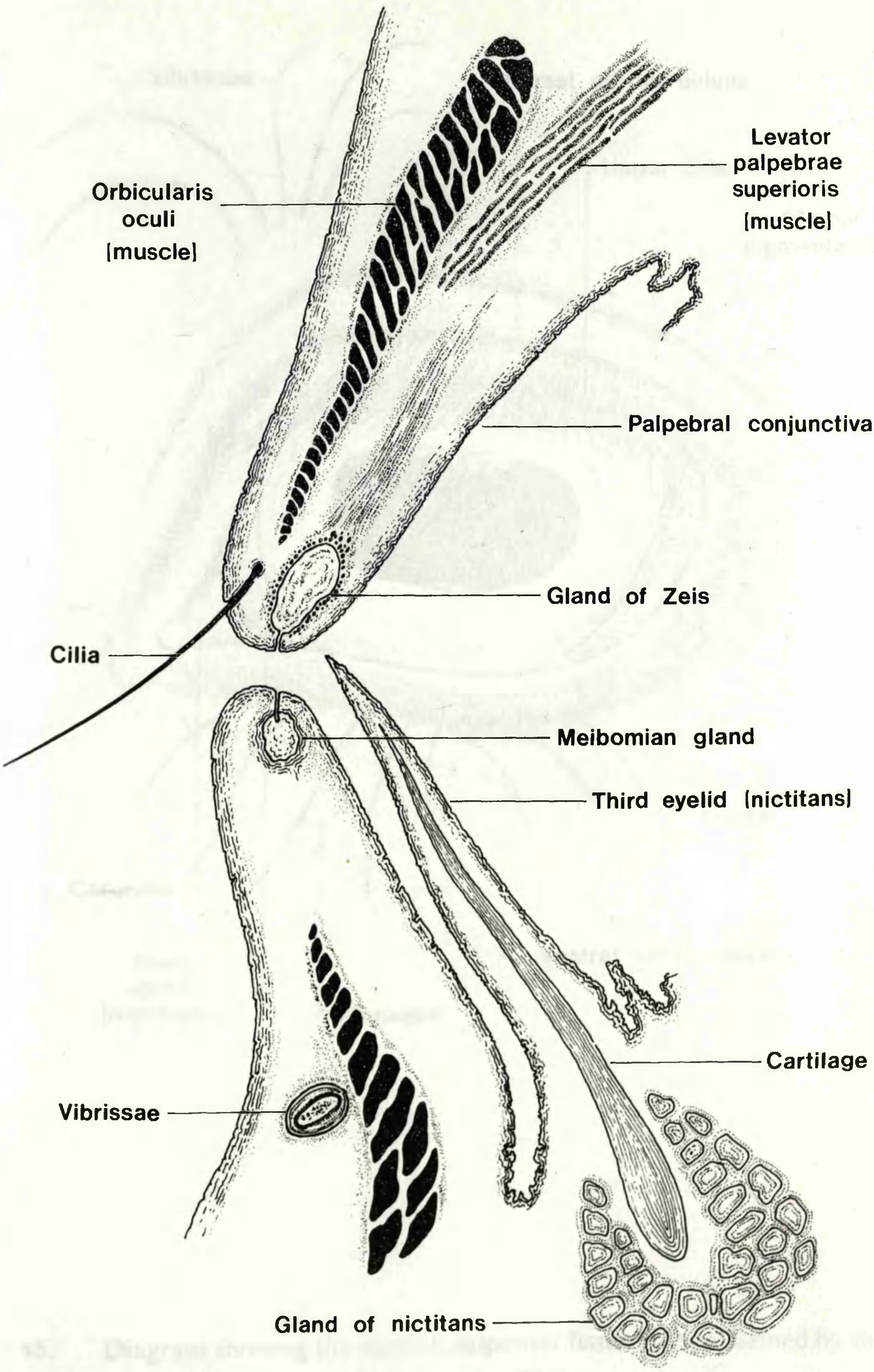
A. B.

41. The normal posture of the eye of an adult horse is such that the pupillary fissure is almost horizontal (A). In the neonatal foal the nasal region of the pupillary fissure is rotated ventrally (B). See also figure 85.

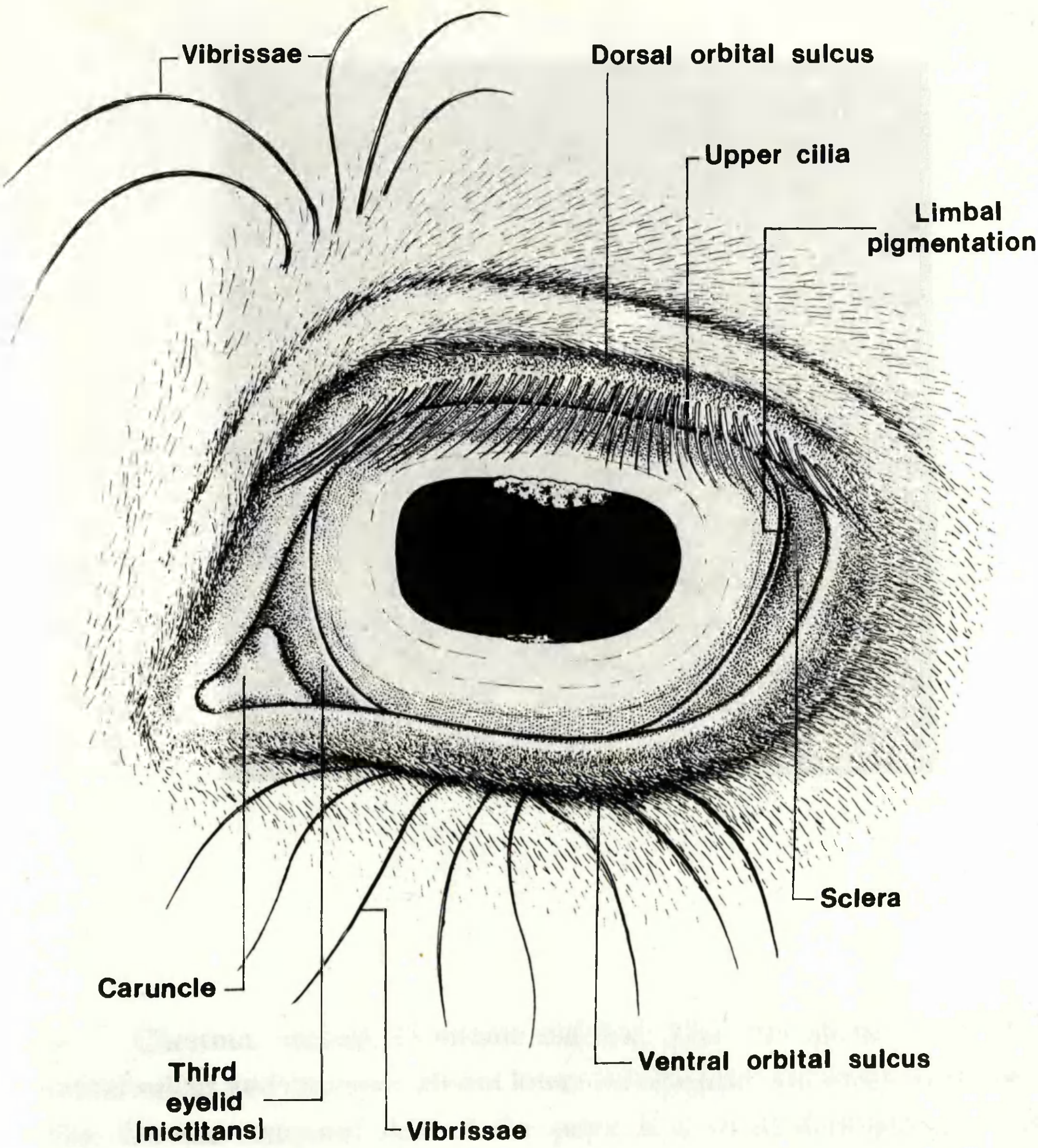
42. Bay, normal, 10 month old foal with prolapse of orbital fat into the anterior episcleral space between the nictitans and the globe. The lesion is seen as a pink mass immediately underneath the reflected nictitans.

	Palpebral	Menace	Corneal
Stimulus	Touch eyelid	Threaten	Touch cornea
Receptor	Ophthalmic branch of V	Photoreceptors of retina	Ophthalmic branch of V
Afferents	Trigeminal (V)	Optic (II)	Trigeminal (V)
Efferents	Facial (VII)	Facial (VII)	Facial (VII)
Effectors	Eyelid muscles	Eyelid muscles	Eyelid muscles
Effect	Blink	Blink	Blink

43. Characterisation of the blink reflex in the horse (after Schmidt and Coulter, 1981).



44. Schematic cross section through the upper and lower eyelids of a horse (after Lavach, 1990).



45. Diagram showing the normal palpebral fissure shape formed by the upper and lower eyelids in a foal (after Lavach, 1990).

46. Chestnut, normal, 15 minute old foal. This view shows the lower eyelid orbital sulcus and vibrissae, absent lower lid cilia and, still wet, long dense, upper cilia. On the temporal side of the pupil is a small dark posterior capsular remnant of the hyaloid artery.

47. Chestnut, normal, 6 hour old foal. This view clearly shows the dorsal and ventral orbital sulci and unpigmented eyelid margins. The long, dense upper and short, sparse lower cilia are visible, as is a single vibrissae running downwards across the eye near the temporal canthus. A 75% oval, slightly wider nasally pupil, and whole-coloured pink nictitans are also seen. Note the normal diameter, complete, clear hyaloid artery on the nasal (medial) side of the pupil.

48. Chestnut, normal, foal. A 50-60% oval post-stimulation pupil is visible in this typical eye of a chestnut foal, with unpigmented eyelid margins, whole-coloured pink nictitans, unpigmented limbal area and mottled grey iris. The long, dense upper and short, sparse lower cilia are also typical.

49. Light chestnut, normal, 17 hour old foal. A grey, mottled iris with 2, dorsal, moderate, irregular corpora nigra. The pupil is 70-75% elliptical. A whole coloured pink nictitans and pink caruncle are visible in the nasal canthus. The long, dense, upper cilia are prominent with the short and sparse lower cilia most obvious nasally against the unpigmented lid edges.

50. Chestnut, normal, 15 hour old foal. This view of the external eye shows a folded lower eyelid in the right eye (excessive orbital sulcus) with palpebral margins in normal opposition to the cornea. The lower lid vibrissae are seen ventrally and the long upper cilia radiate over the palpebral fissure. No lower cilia are present.

51. Chestnut, normal, 18 hour old foal. This external view shows the upper eyelid orbital sulcus, vibrissae (approx. 4) and long, dense upper cilia. The whole-coloured pink nictitans is seen in the nasal canthus.

52. Chestnut, normal, 11 hour old foal. A single dorsal vibrissae, long and dense dorsal cilia, short sparse lower cilia, and approximately 6 ventral vibrissae are seen in this view. The unpigmented eyelid margins are particularly obvious. The pupil is 70% oval.

53. Chestnut, normal, 12 hour old foal. The palpebral fissure shape, dorsal and ventral orbital sulci, and upper and lower eyelid cilia are all seen in this external eye view. In the temporal canthus, just to the inner side of the mildly pigmented limbus, is a smokey grey line representing the insertions of the pectinate ligaments. The grey-brown iris with iridescent pupillary margin and normal dorsal corpora nigra is seen surrounding a 70% oval pupil.

54. Bay, normal, 28 hour old foal. This view shows a pink black-edged nictitans, moderate sized dorsal and small ventral corpora nigra, and 75% oval pupil. Note also the heavily pigmented eyelid margins.

55. Bay, normal, 13 hour old foal. The left eye of a foal with unilateral scleral (subconjunctival) haemorrhage in intermittent patches across the entire dorsal sclera, but more intense nasally. Except nasally, the haemorrhage does not extend to the limbus. Long cilia and entrances to the Meibomian glands are seen in the upper eyelid. Pigmentation of the sclera only occurs at the limbus. A scleral overhang or shelf is seen dorsally midway between the canthi. A mottled dark brown iris, with a blue-grey iridescence near the pupillary margin, and prominent dorsal corpora nigra are also seen.

56. Bay, 11 hour old foal, showing mild neurological signs including head tilt, dumbiness and bumping into objects. Above average birth weight with category 3 foaling. The foal recovered to normality in 48 hours with intensive care. This view of the right eye demonstrates clearly the red, fresh, patchy, mild subconjunctival haemorrhage in the dorso-nasal region of the sclera. The haemorrhage barely reaches the limbus (except nasally) and is accompanied by superficial scleral and bulbar conjunctival vessel injection. Note the fresh, slightly more obvious, haemorrhage alongside the enlarged vessel in the centre of the photograph. Also visible is a reddened and inflamed palpebral conjunctiva, pink black-edged nictitans, meibomian gland entrances on the upper eyelid, and long upper cilia.

57. Chestnut, normal, 13 hour old foal. The normal palpebral fissure shape; long dense, dorsal and short, more sparse, ventral cilia; and dorsal vibrissae are all visible in this foal. The unpigmented eyelid margins, whole-coloured pink nictitans and grey-brown/iridescent pupillary margin iris, are all typical of chestnut foals. The 65%, almost elliptical, pupil shape is clearly seen, as is the dorsal and ventral corpora nigra. The translucent remnants of the posterior pupillary membrane are seen in the temporal margin of the pupil.

58. Chestnut, normal, 18½ hour old foal. This view of the nasal canthus demonstrates unpigmented eyelid margins, long dense upper and short sparse lower cilia, a small unpigmented hairless caruncle, a whole-coloured pink nictitans, unpigmented sclera, nasal pectinate ligaments but no grey lines of insertion into the cornea, a grey-brown mottled iris, normal-sized dorsal and small ventral corpora nigra, and a 70% oval pupil. Note the translucent remnant of the posterior pupillary membrane.

59. Bay brown, normal, less then 24 hour old foal. This left eye shows a primary entropion of the lower eyelid which was treated by regular manipulation and antibiotic ophthalmic ointment. It successfully resolved in 48 hours. Also note the 50-60% elliptical pupil, large dorsal corpora nigra, dark brown mottled iris, and thin, dark, lace-like, pupillary membrane collarette just visible in the anterior iris temporal to the pupil.

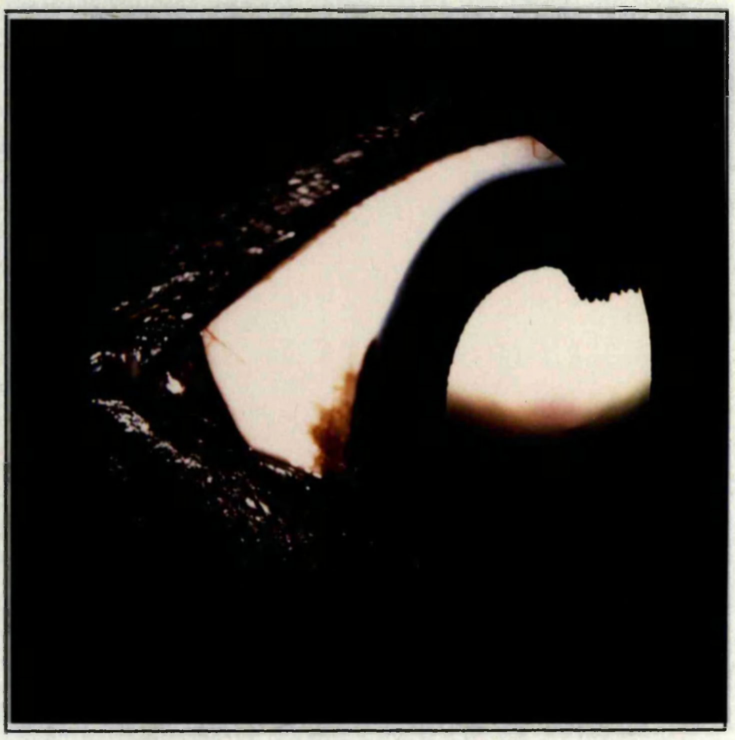
60. Chestnut, abnormal, less than 24 hour old foal. This foal was born with a Group 3 developmental problem involving flaccid tendons of both front and hindlimbs. Subsequently, a bilateral entropion with severe mucopurulent ocular discharge developed. At this stage the entropion is resolved but the dried mucopurulent ocular discharge is evident around the eye, on the eyelids and cilia.

61. Grey, normal, 16½ hour old foal. This view of the nasal canthus shows a pink black-edged nictitans, darkly pigmented caruncle and eyelid margins, dark grey mottled iris with iridescent pupillary margin, and normal sized dorsal corpora nigra. The pupil is 70-75% and oval. Adjacent to the edge of the nictitans is a light blue line, which is the pectinate ligament insertion.

62. Chestnut, normal, 59 hour old foal. This older foal has a more adult type pupil in shape and size (60% oval). The entrances to the meibomian glands are particularly clear in the nasal aspect of the upper eyelid. The everted palpebral conjunctiva is of a normal colour and appearance. A pink whole-coloured nictitans, non-pigmented white sclera, and grey-brown iris with pupillary margin iridescence, are all clearly visible. The dorso-temporal iris has a short persistent pupillary collarette seen as a thin dark line just peripheral to the iridescent margin. Due to the lack of limbal pigment the dorsal scleral shelf is obvious, and just visible are some whitish pectinate ligaments towards the temporal canthus.

63. Bay, normal, 40 hour old foal (see figure 66). The right eye of the foal with corneal vascularisation is shown after a further 24 hours. The bulbar and palpebral conjunctival inflammation has decreased but the vessel injection is still obvious. The limbal pigmentation and pectinate lines are especially clear. The density of the vascularisation has decreased, with individual vessels being seen and the edges becoming more diffuse. The connecting discrete corneal vessels have almost completely disappeared, leaving a clear corneal gap. Note the hair foreign body on the cornea.

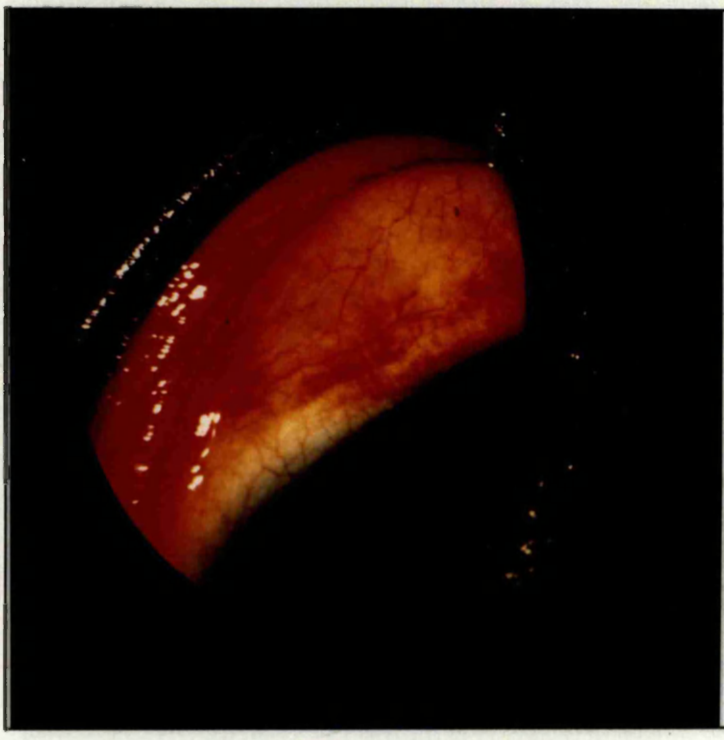
64. Strawberry roan, 2 month old, Welsh Mountain foal. This foal was born with a posteriorly dislocated lens. The foal has a heterochromia irides with pupil distortion. The variable accumulation of pigment at the limbus is particularly obvious.



65. Bay, normal, foal. A heavily pigmented nictitans edge is visible in the nasal canthus. The sclera is pigmented in patches with intermittent concentration at the limbus. Adjacent to this limbal pigment is the blue line of the termination of pectinate ligaments in the cornea.

66. Bay, normal, 16 hour old foal. The right eye of this foal shows a reddened, inflamed upper palpebral conjunctiva and injected bulbar subconjunctival vessels with a reddened sclera. There is prominent dorsal limbal pigment accumulation and pectinate lines. Nearly the entire length of the dorsal limbal cornea, some 3mm inwards fram the limbus, is affected by a solid fringe of corneal vascularisation or pannus. This is connected to the limbus by discrete straight corneal vessels.

67. Bay-brown, normal, 16 hour old foal. The slightly everted upper eyelid shows the long dense cilia of this lid, and mildly swollen, reddened palpebral conjunctiva. In the centre of the pupil the upper part of the Y suture can just be discerned.



68a. Bay, normal, 34 hour old foal. Subconjunctival haemorrhages overlying dorsal sclera. There are two discrete areas, dorso-temporal (68a) and dorso-nasal (68b), of fresh, red, patchy haemorrhage which run up to, and are slightly denser at, the limbus.

68b. Bay, normal, 34 hour old foal. Subconjunctival haemorr hages overlying the dorso-nasal sclera.

69. Chestnut, normal, 38 hour old, foal. This left eye has a pink, black-edged nictitans.

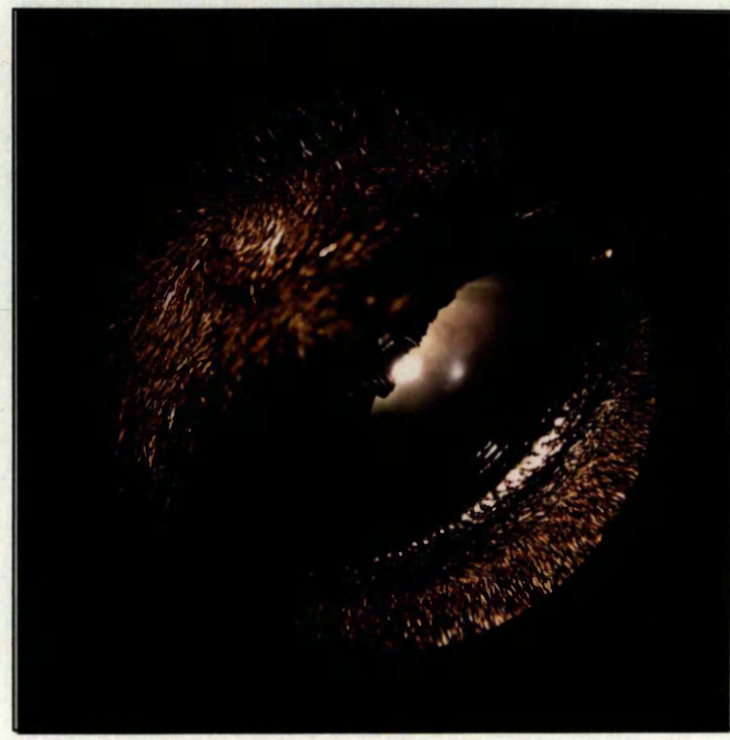
70. Chestnut, normal, 38 hour old foal. The right eye (see figure 69) has a whole-coloured pink nictitans. Note the unpigmented sclera and longer, more dense, lower eyelid cilia in this eye.

71. Chestnut, normal, 15 minute old foal. This view shows the unpigmented eyelid margins, pink with black edge nictitans, and unpigmented nasal canthal sclera. The pupil is 70% oval and there are 3 very prominent dorsal corpora nigra. Part of the Y shape of the posterior suture pattern of the lens is visible.

72. Bay-brown, normal, 15 minute old foal. A pink, black edge nictitans, unpigmented dorsal sclera and reddened palpebral conjunctiva are seen in this view. Within the pupil, Y-shaped, translucent, almost ghost-like, persistent pupillary membranes are seen on the posterior capsule of the lens.

73. Bay, normal, 40 hour old foal (see figure 78). The left eye of the foal with corneal vascularisation is shown after a further 24 hours. The bulbar and palpebral conjunctival inflammation has decreased markedly with only slight injection in the palpebral vessels. In a similar way to the right eye, the corneal vascularisation has decreased in density, with no visible connecting corneal vessels to the limbus. The areas of vascularisation in this eye are more diffuse and patchy, with no individual vessels being evident.

74. Bay, normal, 31 hour foal. The left eye showing the detached clear remnant of the hyaloid artery on the posterior lens, just to the nasal side of the centre. A small, translucent, posterior pupillary membrane is present, immediately adjacent to the pupillary margin ventro-temporally. The pupil is 80% round, with a slightly small dorsal corpora nigra, and a grey-blue (especially pupillary margin) iris. Note the prominent limbal pigmentation and palpebral shape.

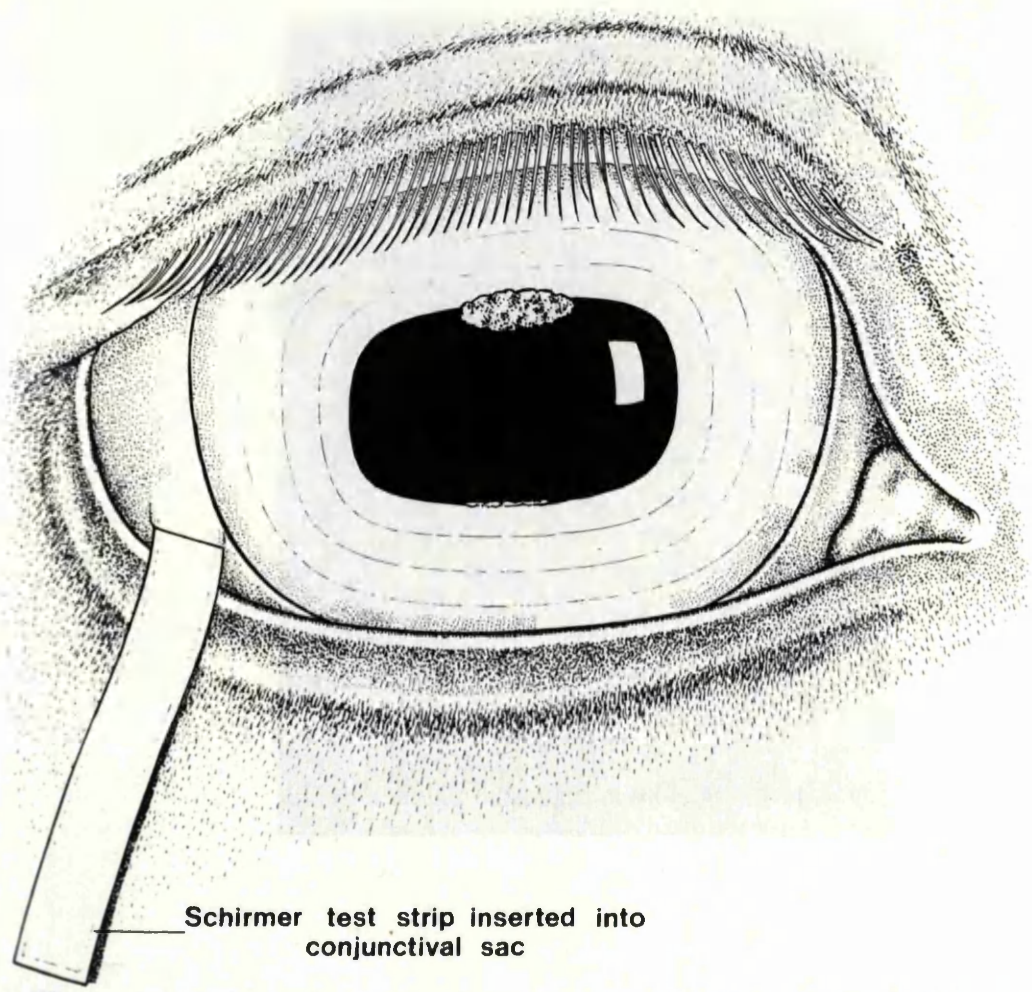


75. Dark brown, normal, 14 hour old foal. Besides a very dark brown, mottled iris colour, this foal had excessive amounts of pigmentation in its sclera. It is not possible from this view to detect the limbus.

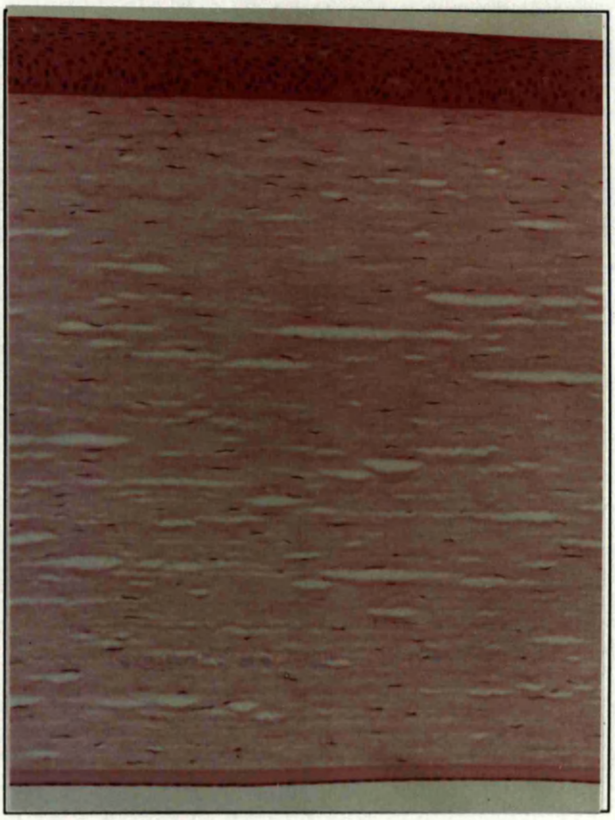
76. Bay, normal, 6½ hour old foal. This view of the temporal canthus shows a dark brown, mottled iris, prominent dorsal corpora nigra, mild patchy scleral pigmentation, intense limbal pigment, and the start of a scleral shelf dorsally.

77. Bay, normal, 60 hour old foal. Magnified view of the dorso-nasal sclera and nasal canthus. A pink, black-edged nictitans and hair arising from the caruncle are seen within the canthus. The accumulation at the limbus, and mild peppering of pigment in the sclera is shown with normal episcleral and bulbar conjunctival vessel appearance.

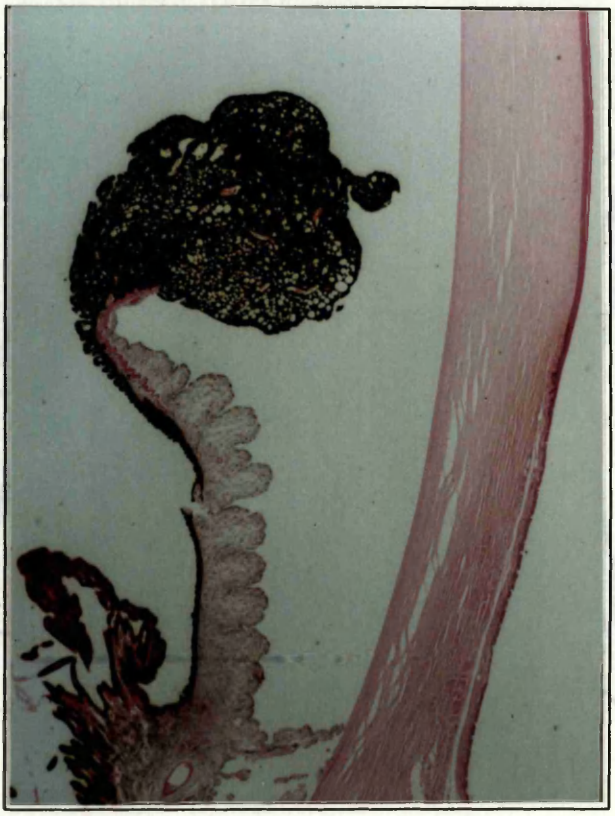
78. Bay, normal, 16 hour old foal. The left eye of this foal shows a reddened, inflamed, upper palpebral conjunctiva and injected bulbar subconjunctival vessels with a reddened sclera. There is prominent dorsal limbal pigment accumulation and, immediately adjacent, a blue-grey line representing the insertion of the pectinate ligaments. Careful scrutiny of the dorsal cornea, especially on the nasal side, reveals 3 areas of corneal vascularisation or pannus.



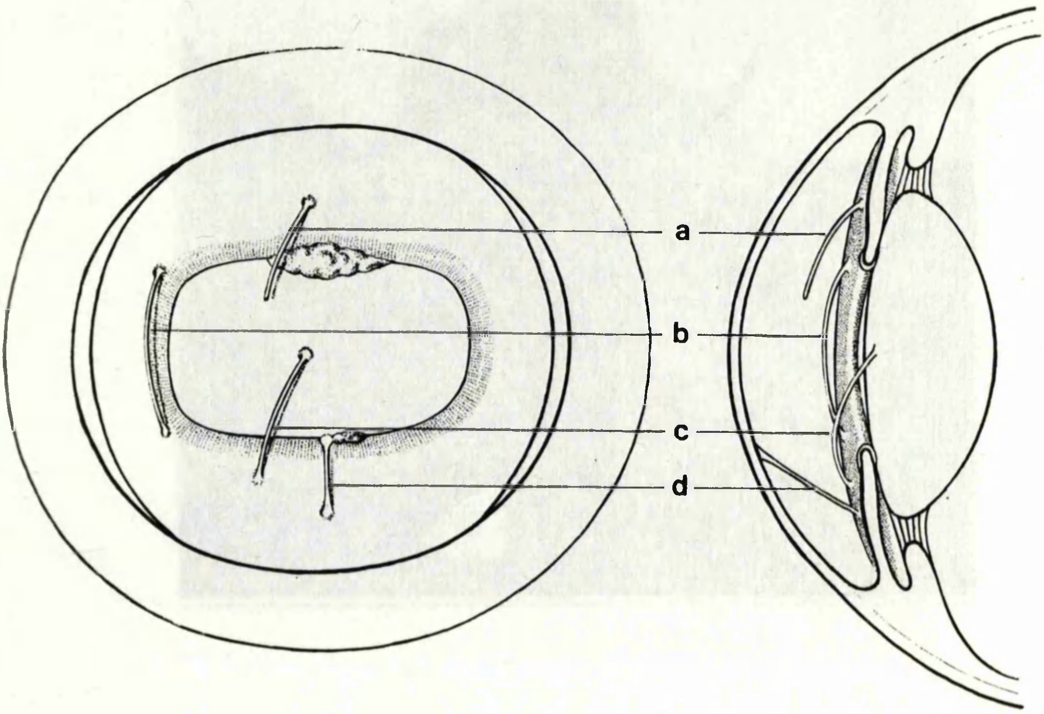
79. Diagram of the Schirmer tear test, which involves inserting a test strip into the conjunctival sac and measuring the length of absorption along the paper.



80. A histological cross section of a normal cornea of a foal. The layers from the top downwards are: 1) The non-keratinised stratified squamous epithelium and its basement membrane; 2) The corneal stroma consisting of stromal cells and collagen lamellae; 3) The elastic Descemet's membrane, which acts as the basement membrane for; 4) The single layer endothelium.

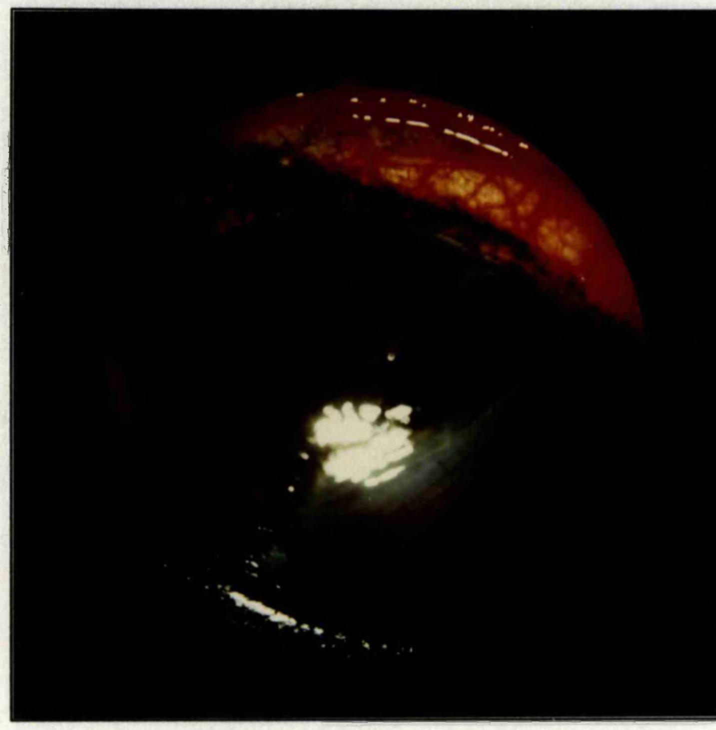


81. A photomicrograph of the iris, ciliary body and cornea of a foal's eye. The multilayered cornea is seen to the right. Situated at the pupillary margin is the dorsal corpora nigra, which is an extension of the heavily pigmented posterior pigment epithelium of the iris. The iris sphincter muscle is seen in the central stroma near the pupillary margin and corpora nigra. The heavily pigmented pars plicata of the ciliary body is seen below the iris, and contains large numbers of fenestrated blood vessels.



82. Schematic diagram to show how Persistent Pupillary Membranes (anterior PPM) may float freely in the anterior chamber (a), and/or be attached to other sites on the iris (b), lens (c) or cornea (d) (after Lavach, 1990).

83. A subpalpebral lavage system and third eyelid flap used in an adult thoroughbred with a chronic, corneal ulcer.



84. A 6 month old, Thoroughbred foal with a large perforating wound of the cornea from limbus to limbus. The wound is plugged by iris, fibrin and other exudate. Note the thickened, oedematous corneal edges and injected scleral blood vessels.

85. Bay, normal, 2 hour old foal. In the nasal (medial) canthus a nictitans with a pink, black edge colouration is clearly visible, partially overlying the sclera which has a prominent limbal accumulation of pigment. Immediately adjacent to the limbus is a blue-grey line representing the insertion of the pectinate ligaments. The dark brown iris has a bluish iridescence adjacent to the dorsal corpora nigra. Note the mild, ventrally rotated, nasal pupillary fissure.

86. Bay-brown, normal, 16 hour old foal. A detailed view of the temporal canthus shows the blue-grey line of the insertion of the pectinate ligaments, a dark brown iris with very short collarette of persistent pupillary membrane, and limbal pigmentation.

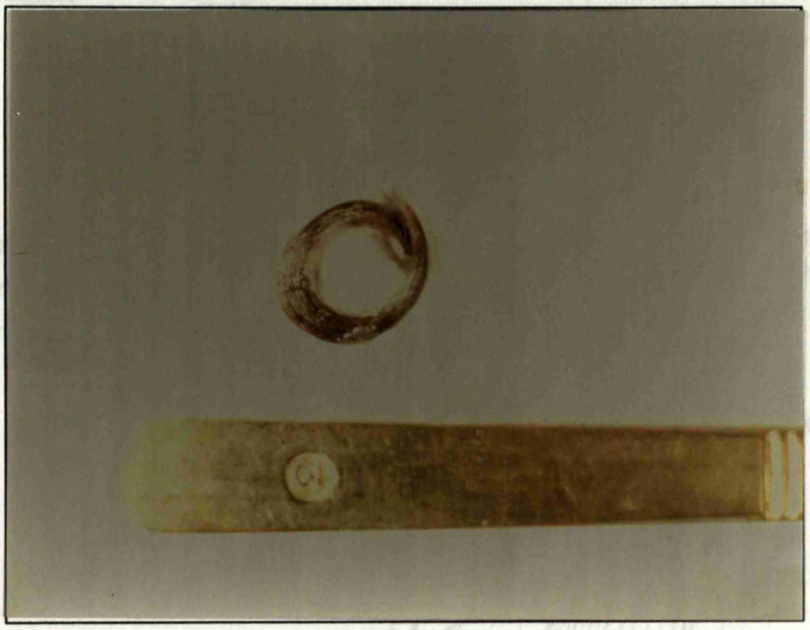
87. Chestnut, normal, 59 hour old foal. A magnified view of the dorsal limbus clearly demonstrates the scleral shelf or overhang, and lack of limbal pigment.

88. Bay, normal, 88 hour old foal (see figures 63 and 66) The right eye of the foal with corneal vascularisation 48 hours after the second examination. The conjunctivae are less inflamed. The vascularisation has decreased in size (both length and width), is more diffuse with less evidence of individual vessels, and the limbal gap has increased.

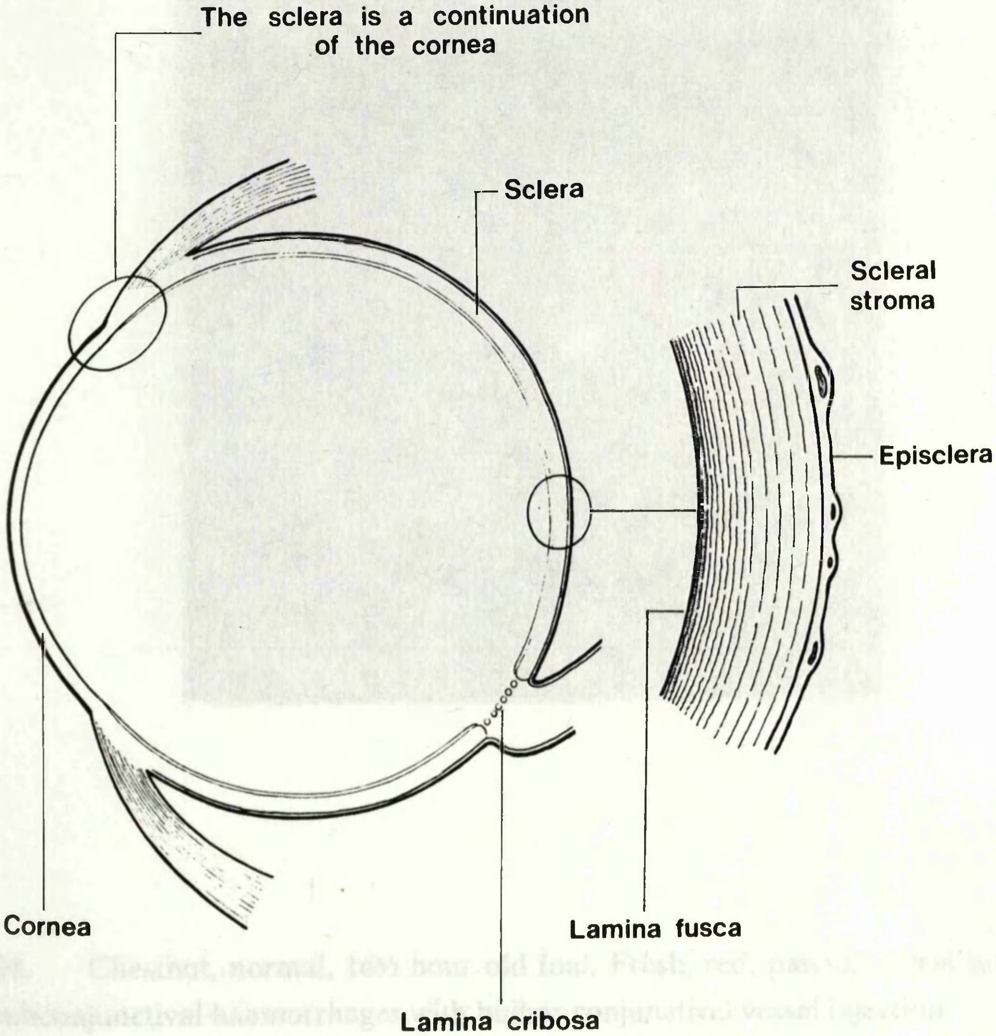
89. Bay, normal, 88 hour old foal (see figures 73 and 78). The left eye of the foal with corneal vascularisation 48 hours after the second examination. The conjunctivae are less inflamed. The patches of vascularisation have become smaller (length and width) and more separated, and the limbal gap has increased.

90. Bay, underweight, dull, abnormal, 14½ hour old foal. The left eye of the foal clearly shows the tightly coiled hairs resting on the cornea. Notice the excessive lacrimation especially from the nasal canthus, and matting together of the upper cilia.

91. Bay, underweight, dull, abnormal, 14½ hour old foal. The hair foreign body has been removed from the right eye. The resultant round, superficial ulcer is clearly visible in the centre of the cornea just above the lower eyelid. The mildly underrun edges of the ulcer (dense opacity) are surrounded by a larger, more diffuse, corneal oedema. Superficial vascularisation of the cornea is seen as a fringe of arborising vessels arising from the dorsal limbus. Also clearly visible is the mottled dark brown iris, intensely pigmented limbus, and long, dense upper cilia.



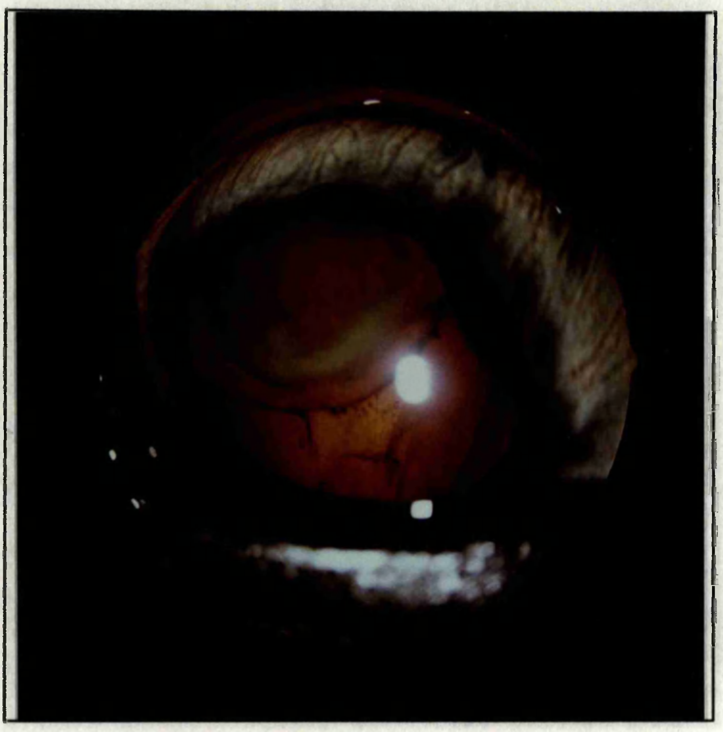
92. The foreign body removed from the right eye shown alongside a scalpel blade handle. The offending article is a tightly coiled ring of strands of hair which is concave on the corneal surface.



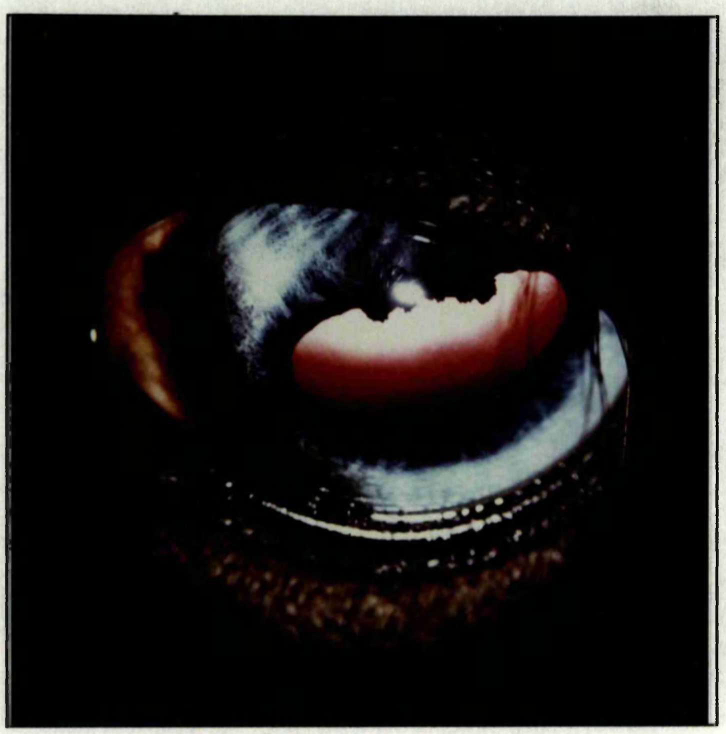
93. A schematic diagram of the sclera.

94. Chestnut, normal, 16½ hour old foal. Fresh, red, patchy, dorsal temporal subconjunctival haemorrhages with bulbar conjunctival vessel injection.

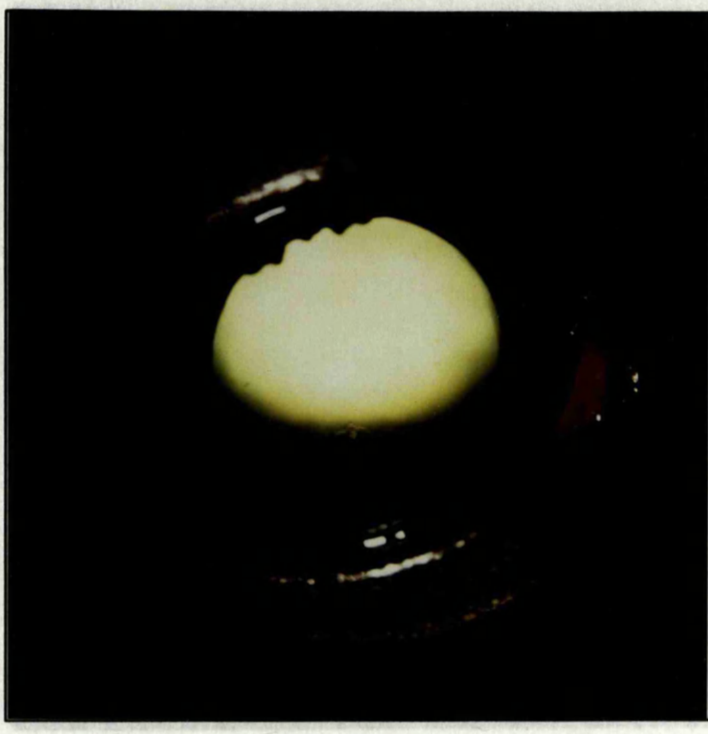
95. A higher powered photomicrograph of the central section of a foal's iris. The bottom densely pigmented line is the double epithelial layer seen resting on their basement membranes. The stroma comprises the bulk of the iris, and contains melanin pigmented cells distributed throughout. Also present is connective tissue, large numbers of blood vessels and nerves. The anterior border or endothelial layer is thrown into folds by the contraction of the dilator muscle.



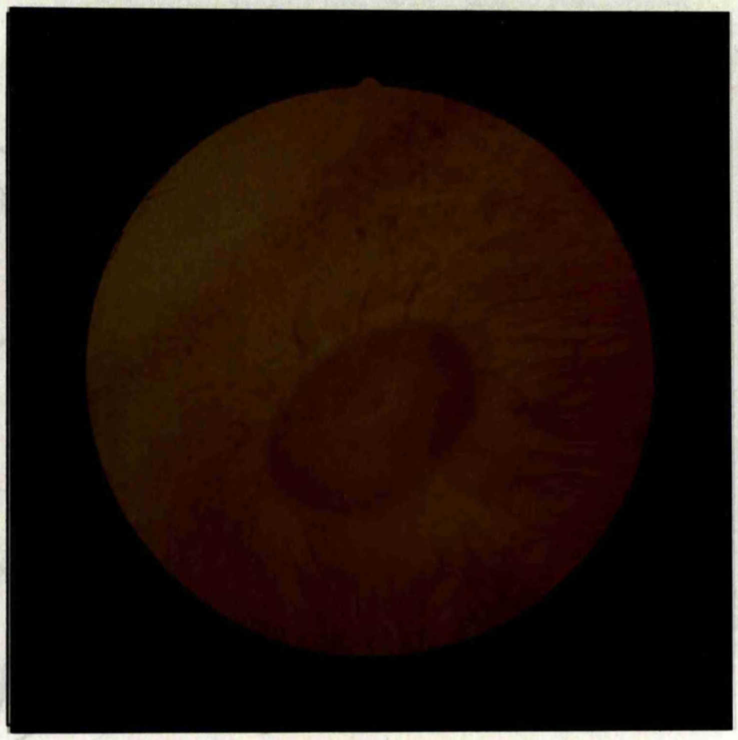
96. Strawberry roan, 2 month old, Welsh Mountain foal (see figure 97). This foal has a posteriorly dislocated lens which has a nuclear cataract. The sheets of material outside the lens equator are the damged lens zonules. The pupil is distorted in shape and larger than would be expected in this age of foal. The heterochromic iris is different in colour and appearance to the normal eye (see Figure 97) and the corpora nigra are shrunken and misshapen. The radial iris vascular pattern is visible through the lightly pigmented iris.



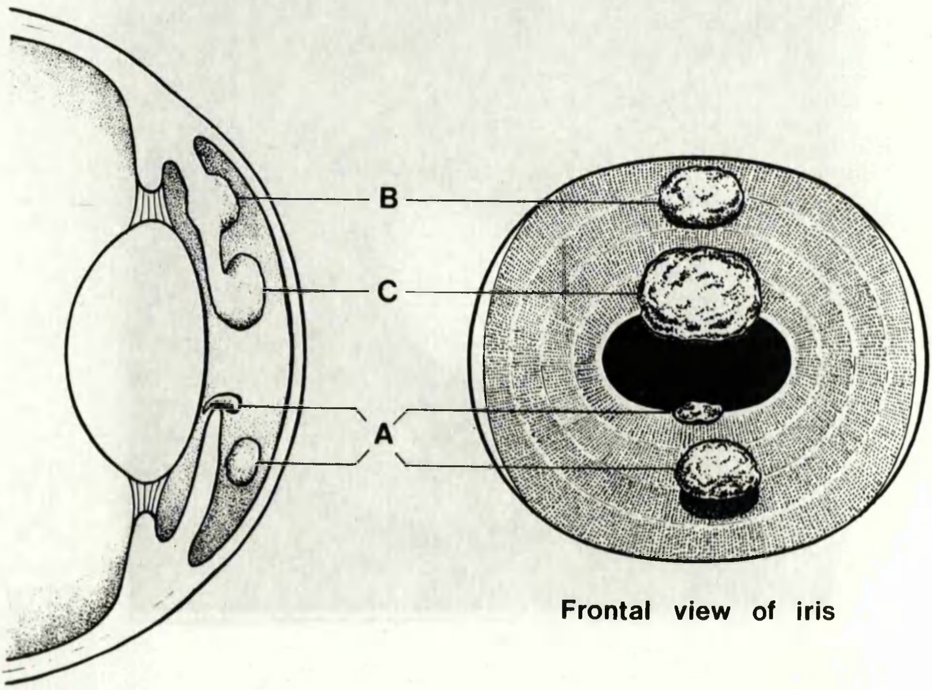
97. Strawberry roan, 2 month old, Welsh Mountain foal (see figure 64 and 96). This is the normal other eye in this foal affected by a congenital lens dislocation. The heterochromia irides and dorsal/ventral corpora nigra are obvious. Notice the difference in shape and size of the latter in this non-affected eye. The pink fundic reflection was due to partial albinism in the tapetal/non-tapetal fundic colouration.



98. Bay, normal, 13 hour old foal. A pink with black edge nictitans is obvious in the nasal canthus. An 80% round pupil is present with a normal sized dorsal corpora nigra. The iris is grey-brown especially towards the pupillary margin. In the ventral part of the pupil, an inverted L shaped, translucent posterior pupillary membrane is present with small amounts of debris at the angle of the vessels. This was associated with the hyaloid artery in figure 138.



99. Peripapillary fundus of a palomino pony (see figure 201) with heterochromia iridis. This subalbinotic fundus has a pale yellow tapetal fundus with red Stars of Winslow, an indistinct border, non-pigmented non-tapetal fundus with prominent red choroidal vessels. The pale, normal shaped optic disc has an indistinct retinal vessel vasculature pattern with two areas ventrally which appear unfocused. These may represent myelin extension from the disc.



Frontal view of iris

Sagittal section

A Free floating (Posterior pigment epithelium)

B Stromal cyst

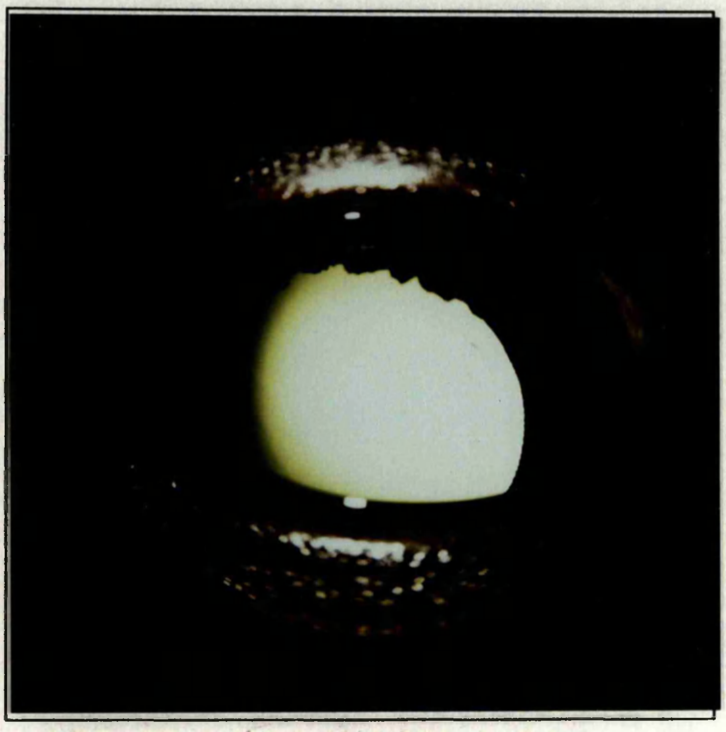
C Corpora nigra

100. Schematic diagram of the three types of cyst arising from the equine iris: A = Cysts of the posterior pigment epithelium, some of which may break off and float through the pupil; B = Stromal cysts often associated with stromal atrophy; C = Cysts of the corpora nigra (after Lavach, 1990).

101. Chestnut, normal, 11 hour old foal. An obvious foreign body of hair and mucoid material is resting on the ventro-temporal cornea. This material lodged on the cornea after examination and before photography. No corneal abnormalities were present and it was easily removed. Note the dense and long upper cilia, and dorsal orbital sulcus. The pupil is approximately a 70% oval.

102. Bay, normal, 2 hour old foal. The normal position of the upper and lower eyelids in relation to the cornea are visible. The iris is overall a dark brown colour, with prominent iridescence dorsally, and some pigment mottling. The pupil is between 60-65% oval, with an obvious dorsal corpora nigra. On the dorso-temporal iris there is a small remnant of the pupillary membrane.

103. Bay, normal, 60 hour old foal. The nasal portion of the lens of the left eye has prominent nuclear rings and ventrally bubbly vacuolation. There is disruption of the lens cortex ventrally and evidence of debris on the lens towards the equator (centre). The pupil is 70% oval. Note the small dorsal corpora nigra.



104. Bay, normal, 6½ hour old foal. A dark brown mottled iris with slight pupillary iridescence and moderate sized dorsal corpora nigra is evident. The pupil is between 75-80% and round.

105. Bay, normal, 11 hour old foal. A 75% oval pupil with a normal size dorsal corpora nigra.

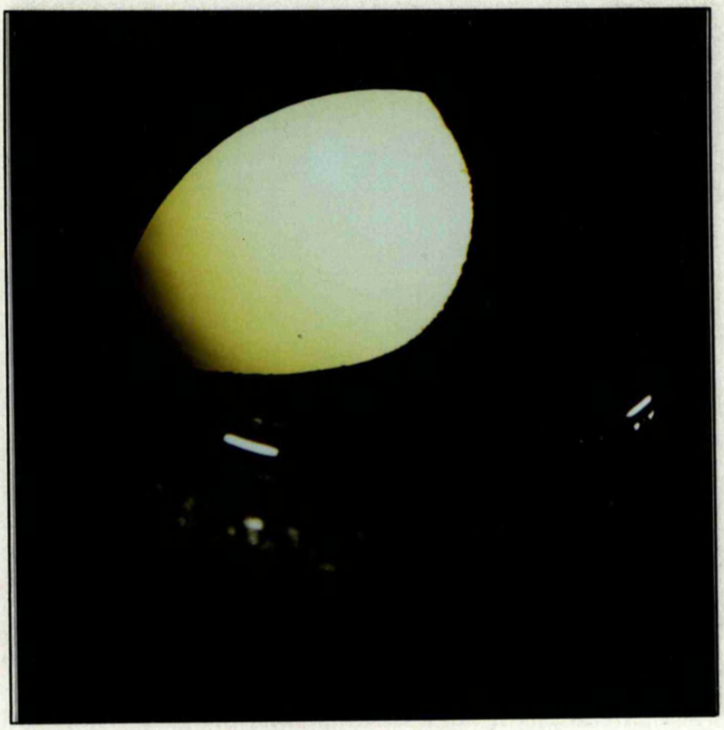
106. Chestnut, normal, 18½ hour old foal. A pigmented, focal opacity of the anterior lens capsule is present just dorsal to the very small ventral corpora nigra, in the ventral pupil. Temporal to this are inverted Y, translucent remnants of the posterior pupillary membrane. The pupil is 70-75% and oval.

107. Chestnut, normal, 39 hour old foal. The iris is grey-brown with an iridescent pupillary margin, and normal-sized dorsal corpora nigra. The pupil is 60% elliptical. This left eye canthus contains three areas of posterior pupillary membrane on the posterior capsule of the lens, seen against the pale pink reflection of the optic disc.

108. An adult Thoroughbred with homogenous dark brown iris, elliptical pupil and moderate sized dorsal and ventral corpora nigra.

109. An adult grey pony with a mottled, dark brown iris showing sectorial variation in pigmentation in the temporal canthus region. Immediately adjacent is the blue-white lines of the pectinate ligament insertions. Note also the scleral pigment concentrated at the limbus and more patchy elsewhere.

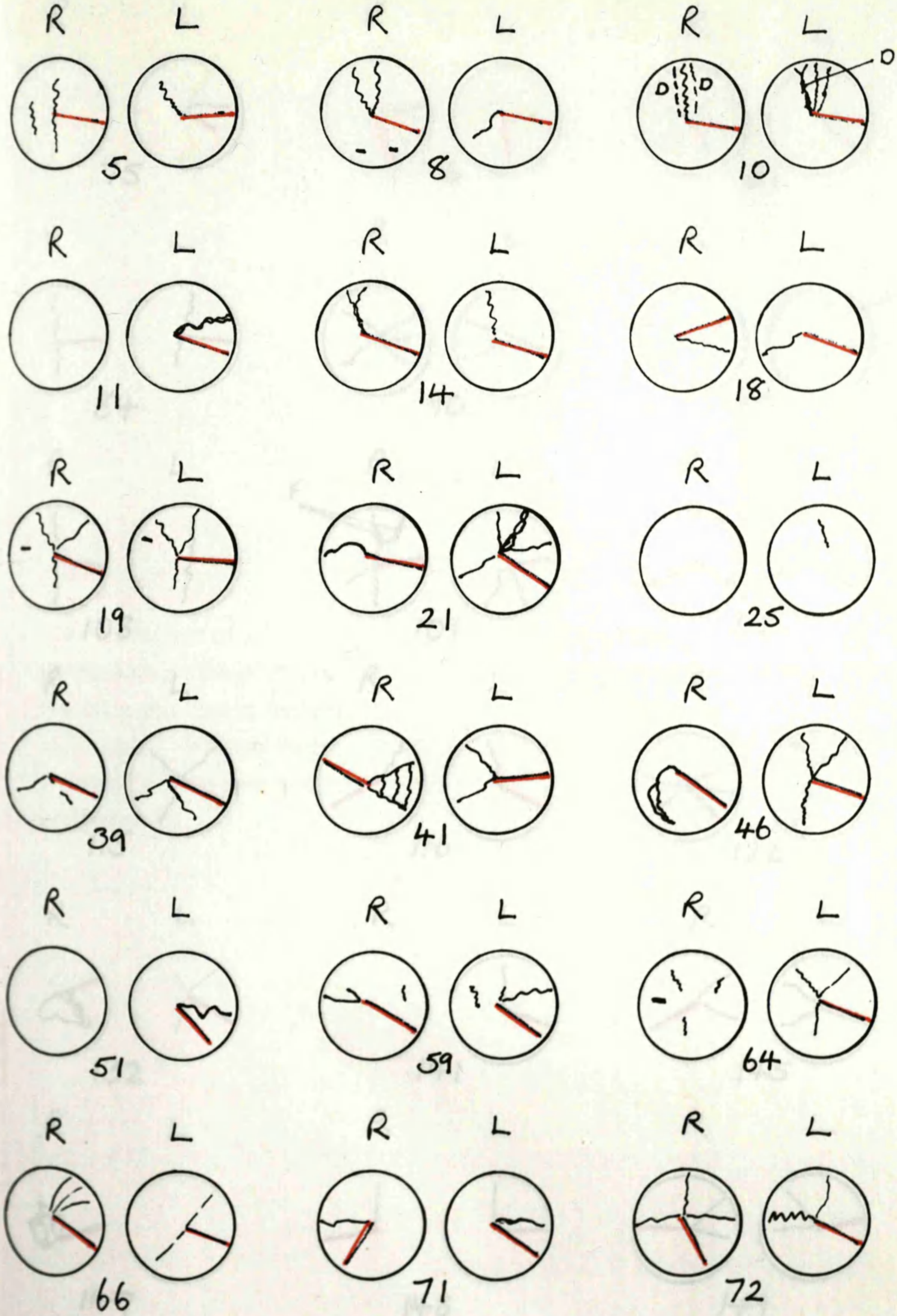
110. Adult, Welsh mountain pony with bilateral heterochromia irides and stromal cystic enlargement within the iris structure mid-dorsally. Trans-illumination indicates that the mass is cystic and differentiates it from a neoplastic lesion.



111. Grey, normal, 16½ hour old foal. The pupillary ruff and very small ventral corpora nigra are seen in this magnified view of the pupil. Note the yellow tapetal fundic reflection.

112. Chestnut, normal, 18 hour old foal. The pupillary ruff is just visible in this magnified view of the nasal canthus as a small undulating fringe on the pupillary margin. This should not be confused with the ventral corpora nigra.

113. Bay, normal, 19½ hour old foal. The dorsal sclera showing normal subconjunctival bulbar vessels and "blueing" due to scleral thinning.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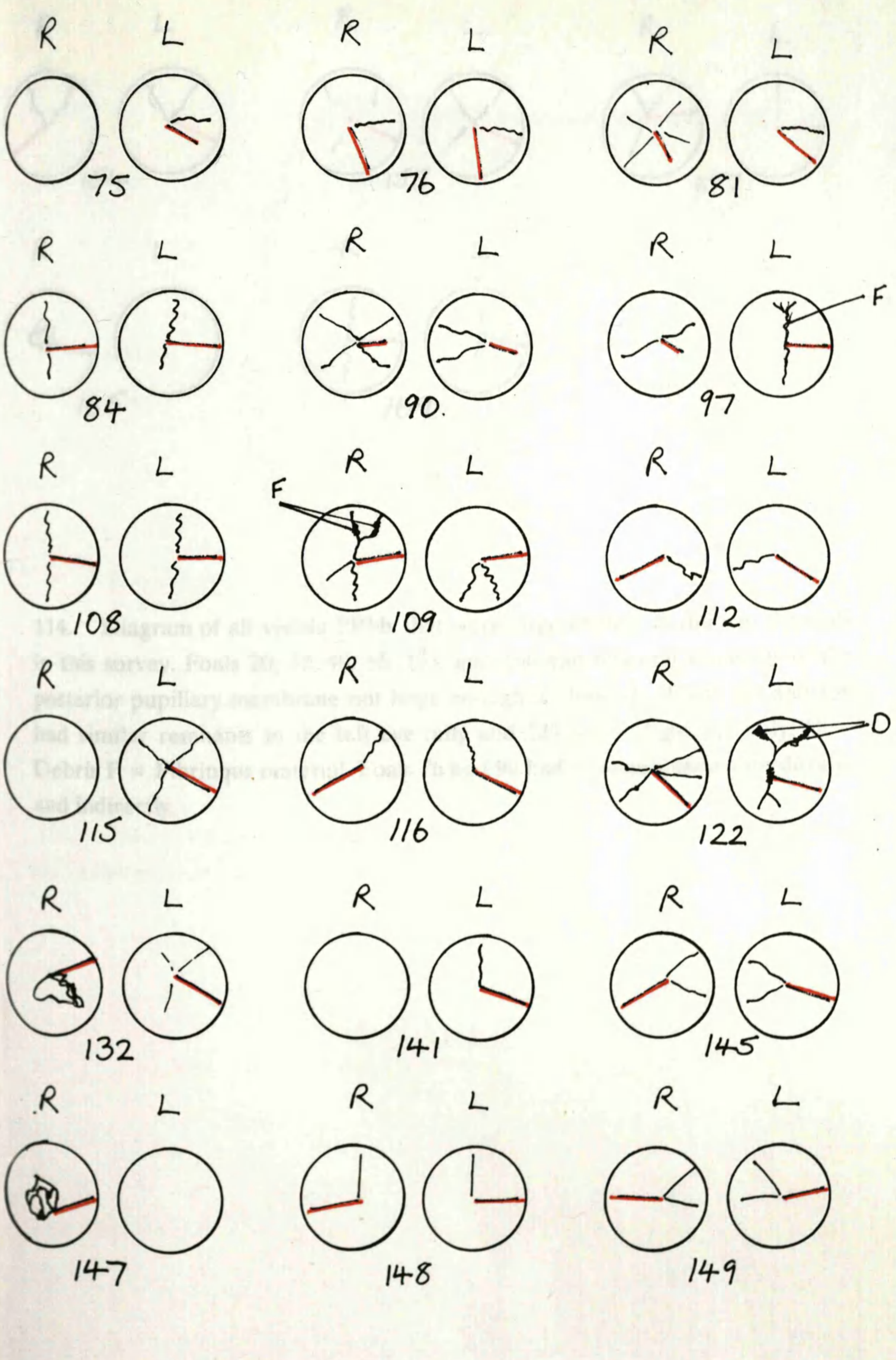
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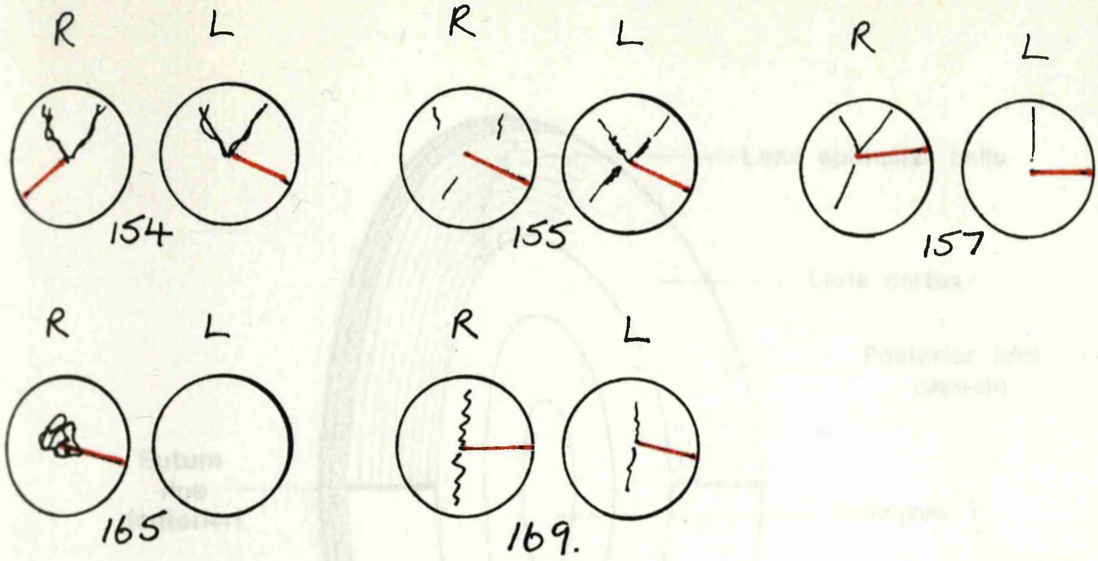
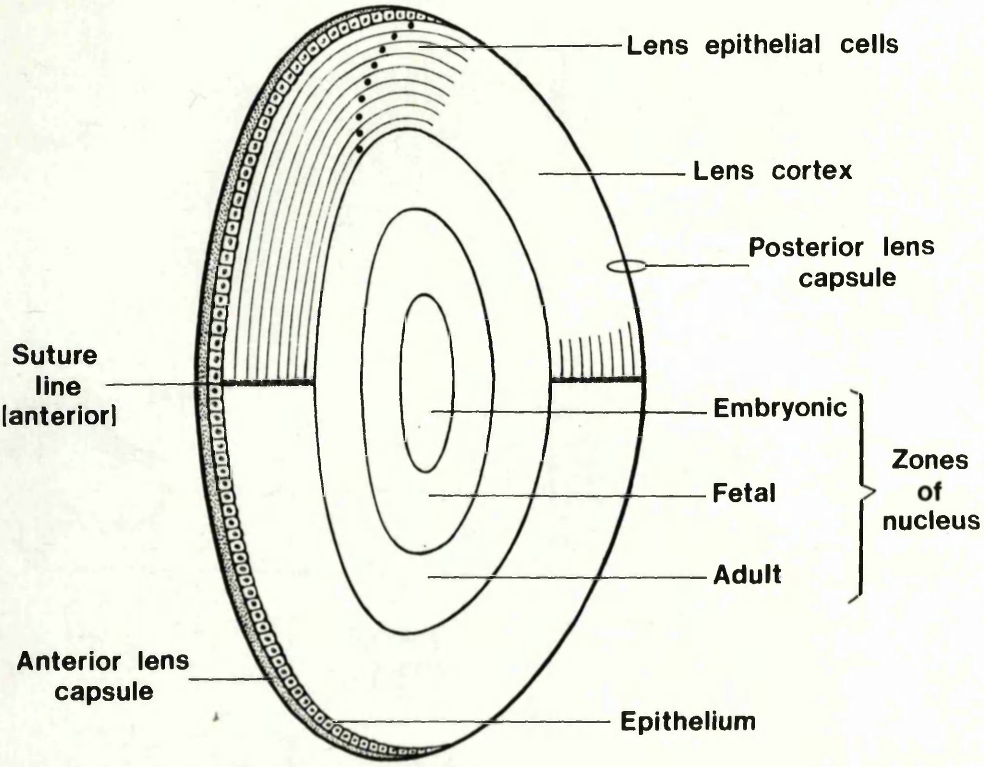
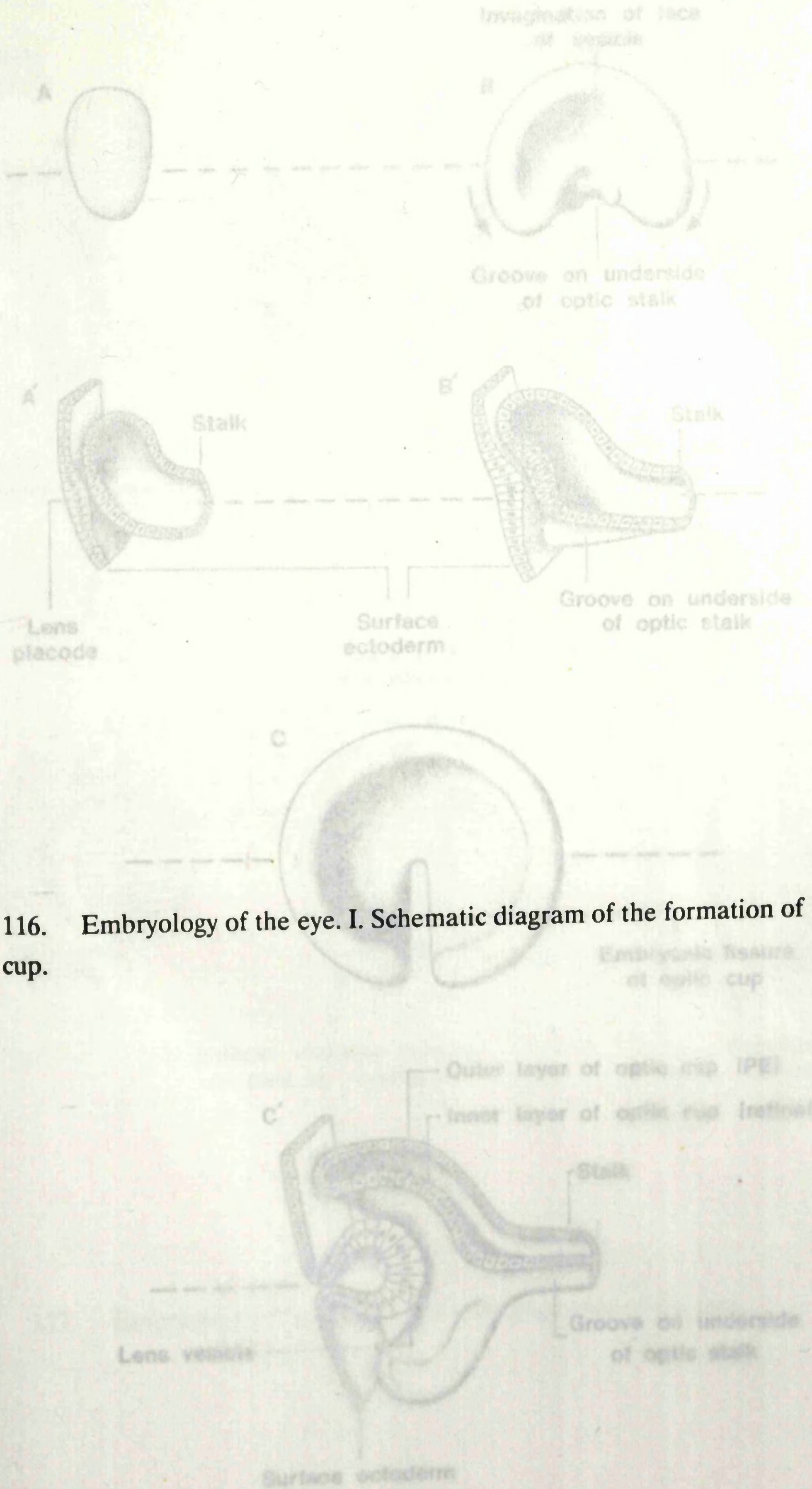


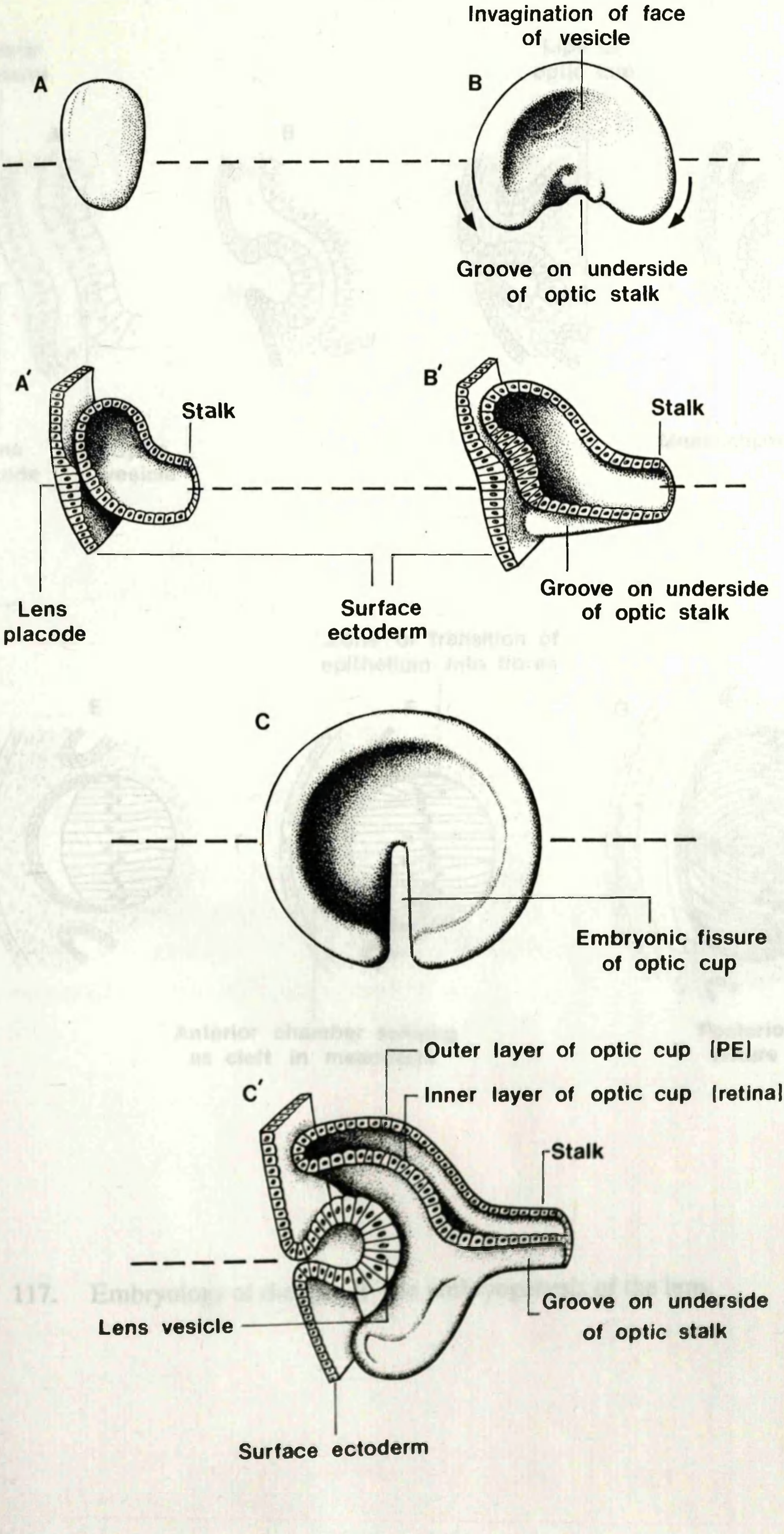
114. Diagram of all visible PPMs that were large enough to draw in the foals in this survey. Foals 20, 32, 49, 56, 133, and 166 had bilateral remnants of the posterior pupillary membrane not large enough to illustrate. Foals 101 and 136 had similar remnants in the left eye only and 129 in the right eye only. D = Debris F = Fibrinous material. Foals 76 and 90 had remnants seen both directly and indirectly.

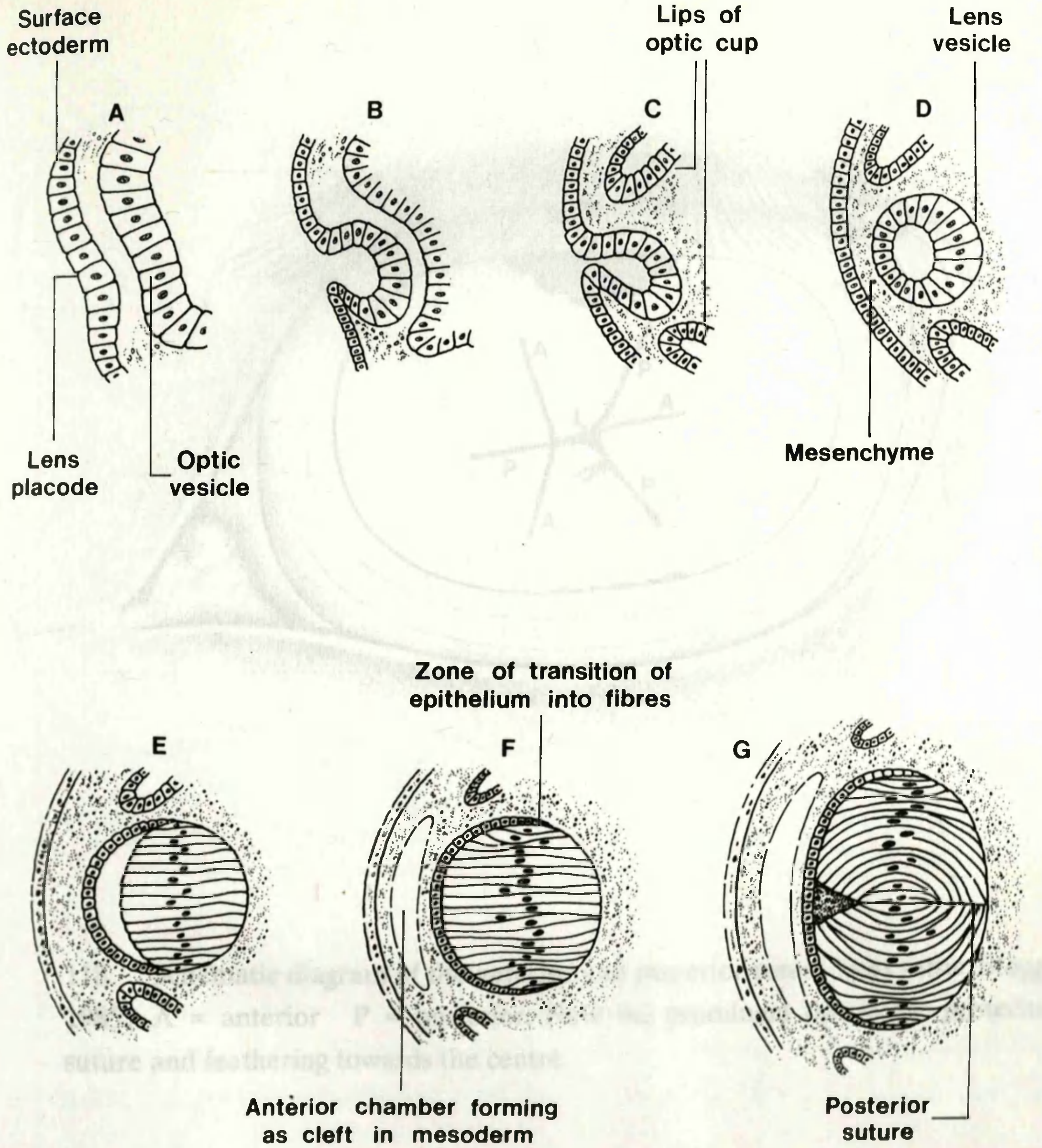


115. Diagram of a midsagittal section through a normal equine lens showing the zones present in the adult.

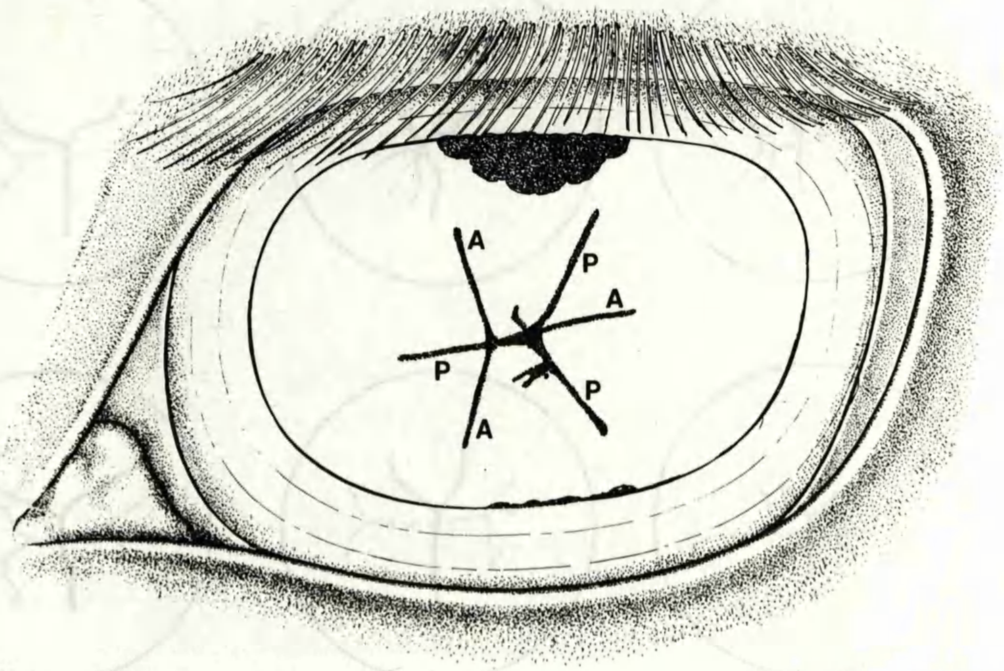


116. Embryology of the eye. I. Schematic diagram of the formation of the optic cup.

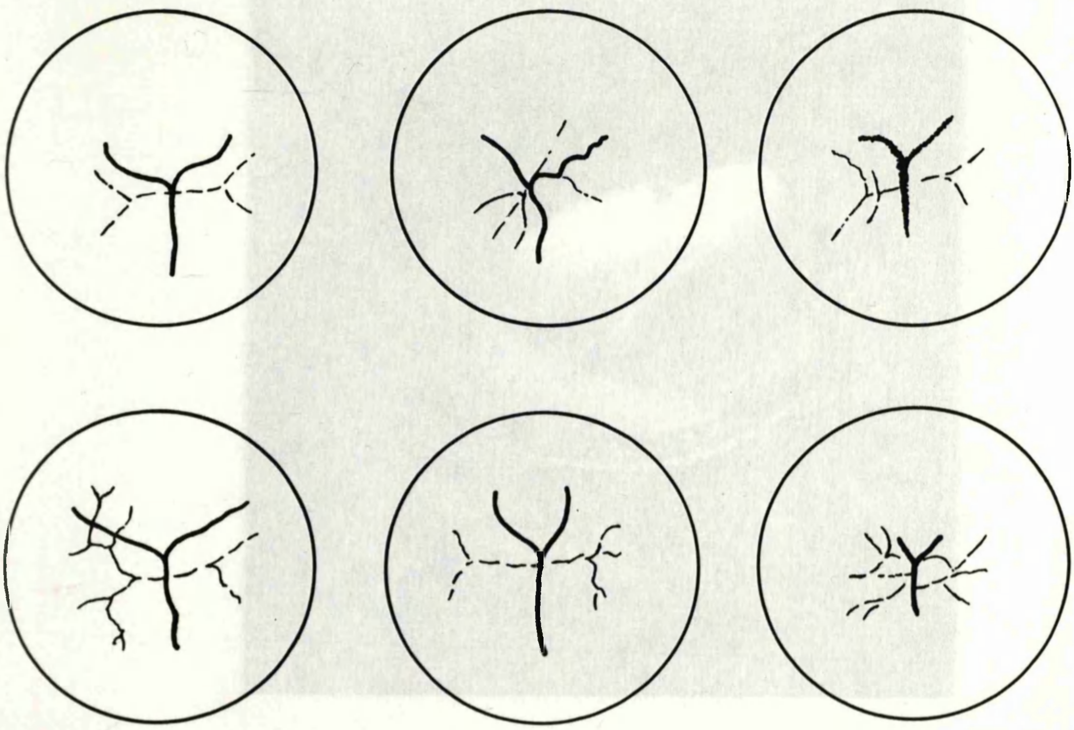

A
B
Invagination of face of vesicle
Groove on underside of optic stalk
A′
Stalk
B′
Stalk
Lens placode
Surface ectoderm
Groove on underside of optic stalk
C
Embryonic fissure of optic cup
C′
Outer layer of optic cup [PE]
Inner layer of optic cup [retina]
Stalk
Lens vesicle
Groove on underside of optic stalk
Surface ectoderm



117. Embryology of the eye. II The embryogenesis of the lens.



118. Schematic diagram of the anterior and posterior suture lines (after Blogg, 1985). A = anterior P = posterior. Note the prominent tips in the posterior suture and feathering towards the centre.



119. Common variations of suture patterns in the normal equine lens. The solid line denotes the anterior Y suture (after Lavach, 1990).

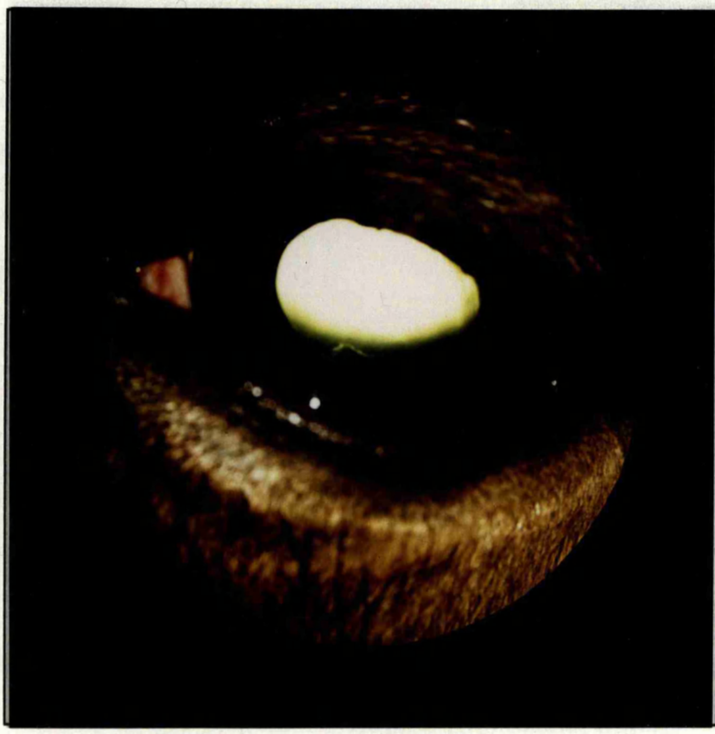
120. Adult horse with an old penetrating injury of the right eye. There is a large area of dense corneal opacity ventrally with a prominent strand from the endothelial surface of the cornea to the anterior lens capsule. There are scattered pigment spots on the anterior lens capsule (iris rests) indicating previous iris-lens adhesions (posterior synechiae).

121. Bay, normal, 31 hour old foal. Right eye showing a posterior pupillary membrane of an inverted L shape but with a more complicated pattern around the origin of the hyaloid artery. The latter is not visible in this photograph. Note the translucent nature of the remnants.

122. Chestnut, normal, 16½ hour old foal. This magnified view of the pupil shows a long, thin, translucent, wavy posterior pupillary membrane running across the equator of the lens to connect with a straight, complete, thin, clear hyaloid artery.

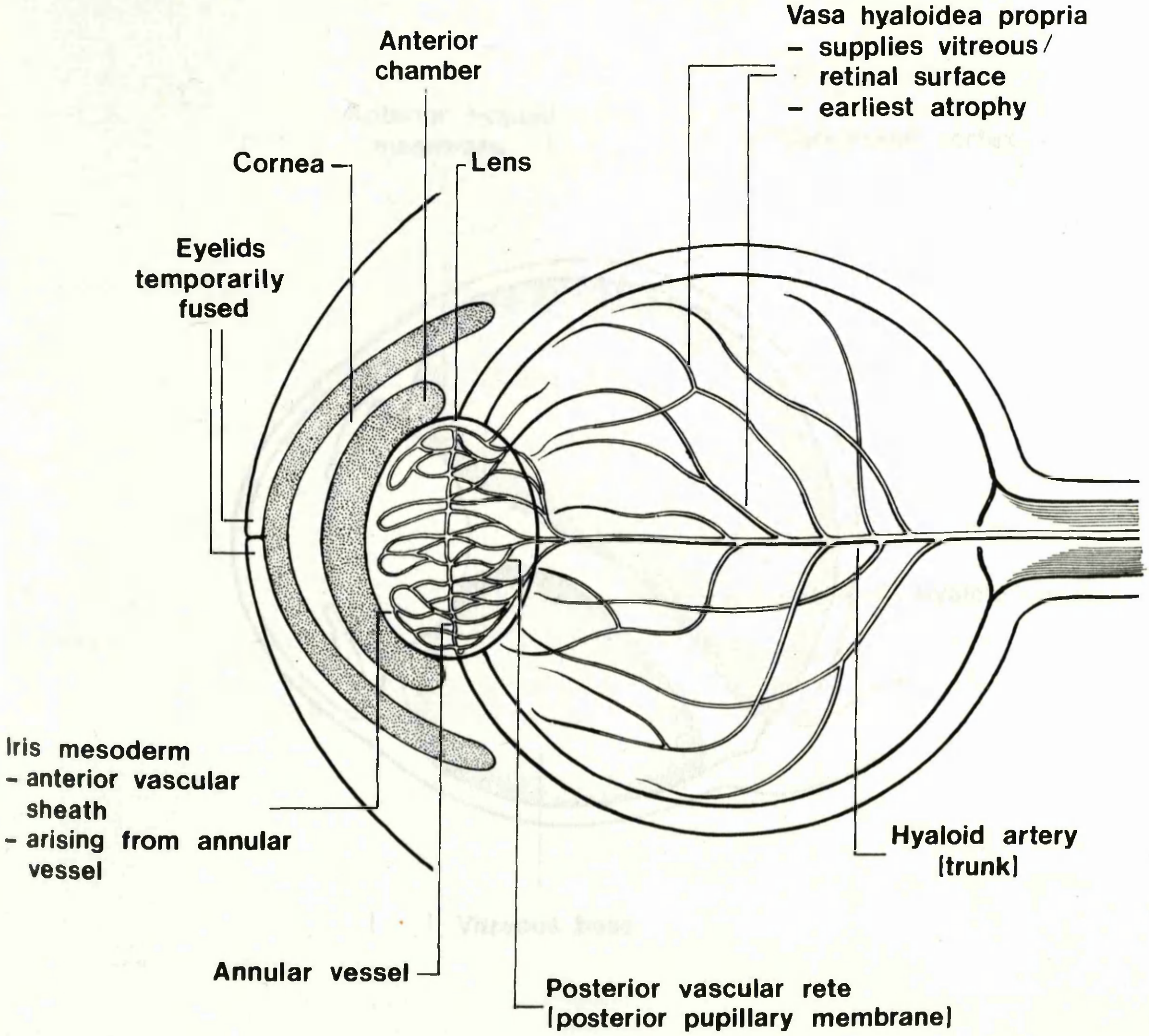
123. Bay, normal, 40 hour old foal (see figure 124) The posterior capsule debris of the posterior pupillary membrane in the right eye has partially resolved and is just visible as ghost structures (translucent) in the pupil at the level of the fundic border reflection.

124. Bay, normal, 16 hour old, foal. The posterior capsular debris of the posterior pupillary membrane is clearly seen in the pupil of the right eye. There is an obvious, translucent, inverted L shape structure with finer parts running towards the angle of the L.

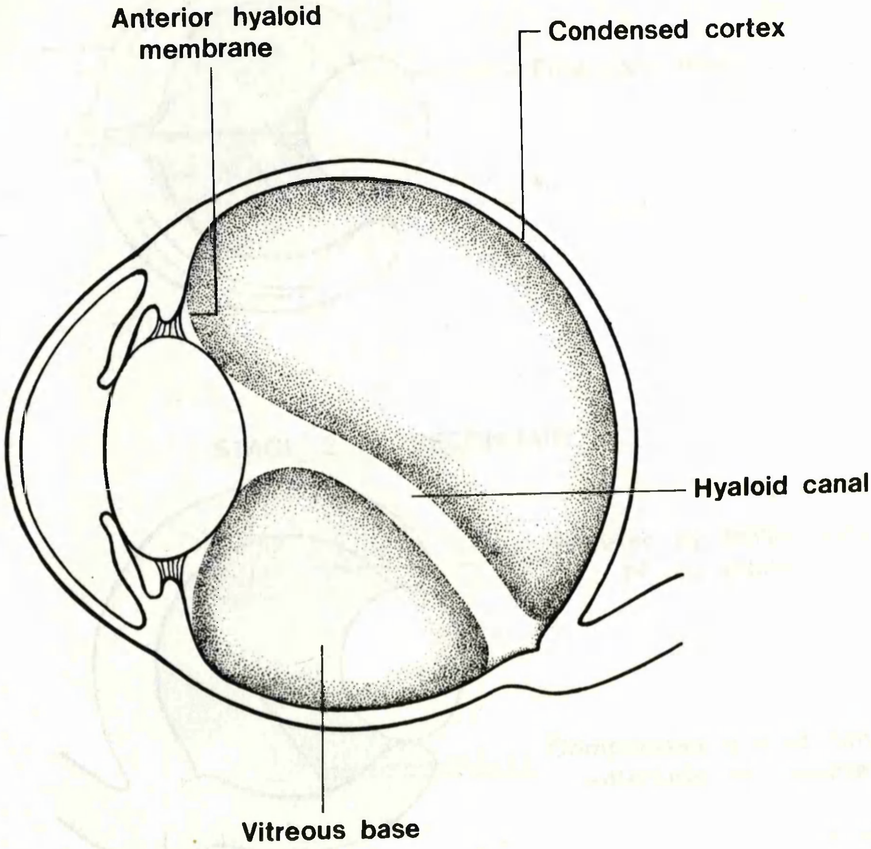


125. Bay, normal, 15 hour old foal. The thin, wavy and translucent posterior pupillary membrane and attached, thin, complete hyaloid artery can just be seen in the ventral pupil as an expanded Y shape.

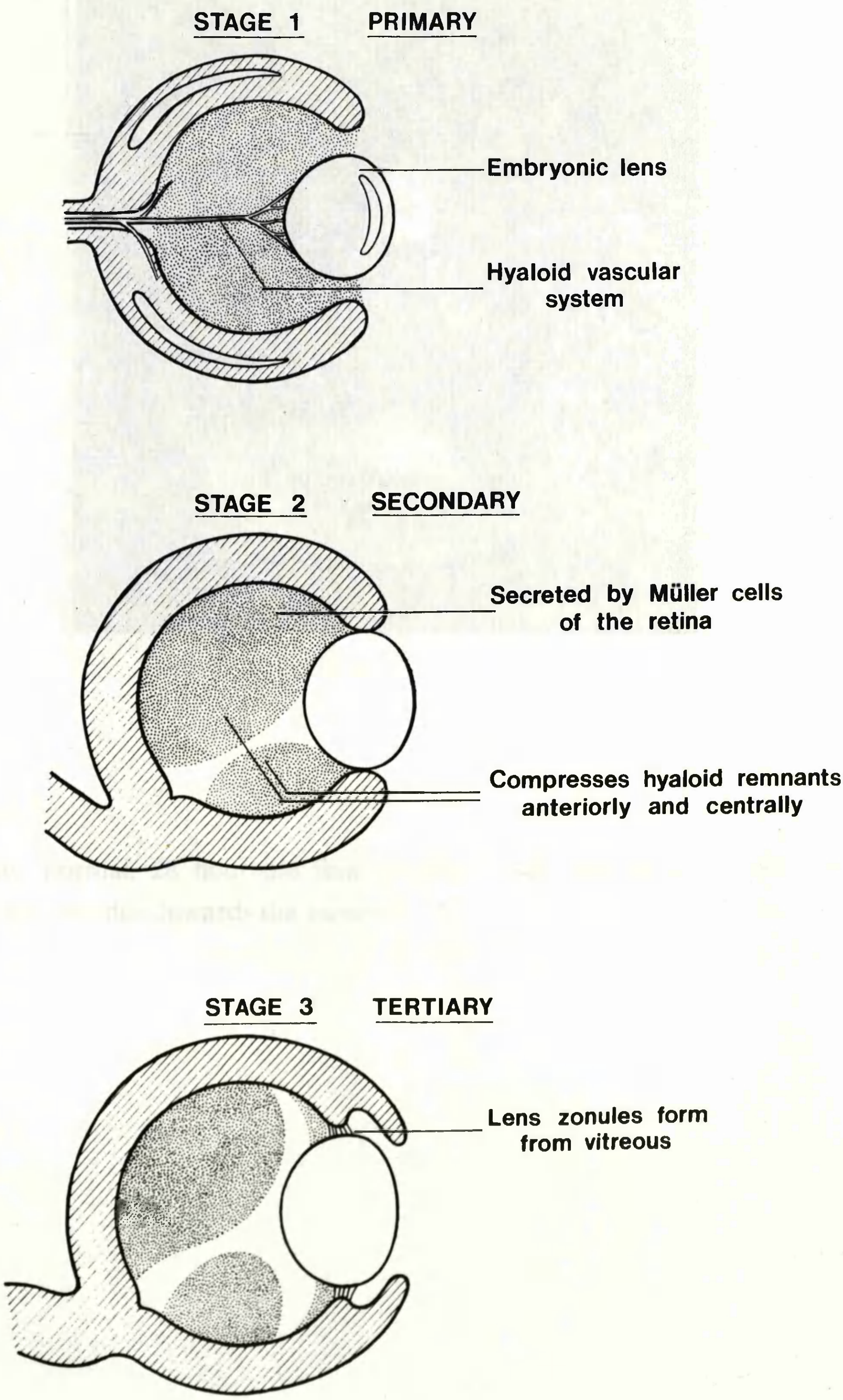
126. Bay, normal, 60 hour old foal. Magnified view of the lens of the left eye showing a temporal cortical cataract, multiple debris on the posterior capsule, and ventral bubbly vacuolation at the nuclear/cortical junction.



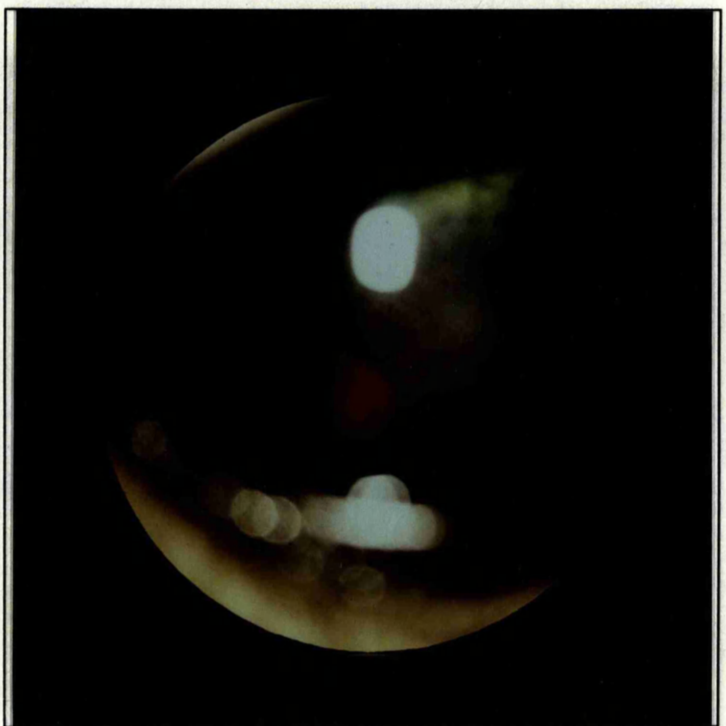
127. A schematic diagram of the hyaloid circulation.



128. Schematic diagram of a mid sagittal section of the vitreous (after Lavach, 1990).



129. Diagram of the stages of vitreous development (after Lavach, 1990).



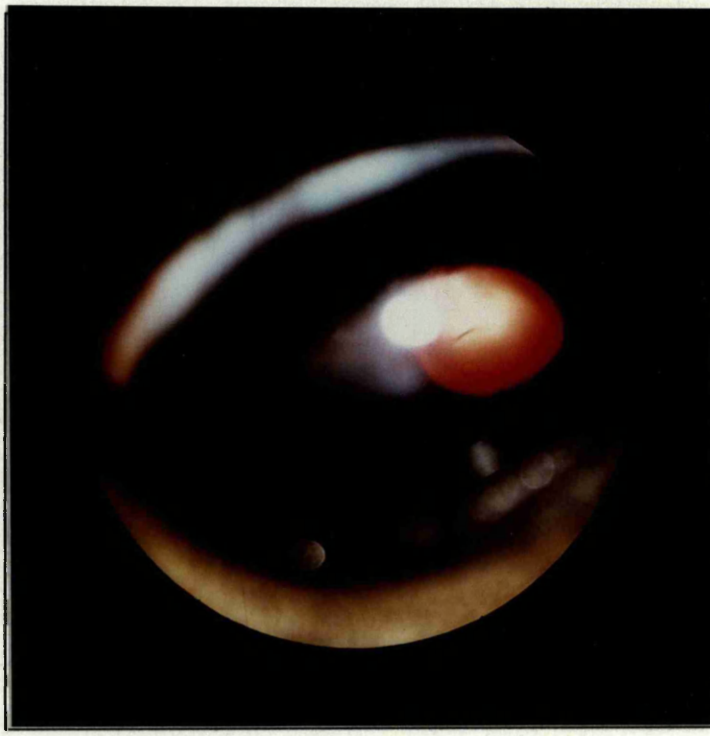
130. Bay, normal, 28 hour old foal. A thin, black, complete hyaloid artery running from the disc towards the camera.

131a. Bay, normal, 12 hour old foal. Left eye of a foal with a complete, thick, red and twisted hyaloid artery running from the pink homogenous disc to the posterior lens capsule.

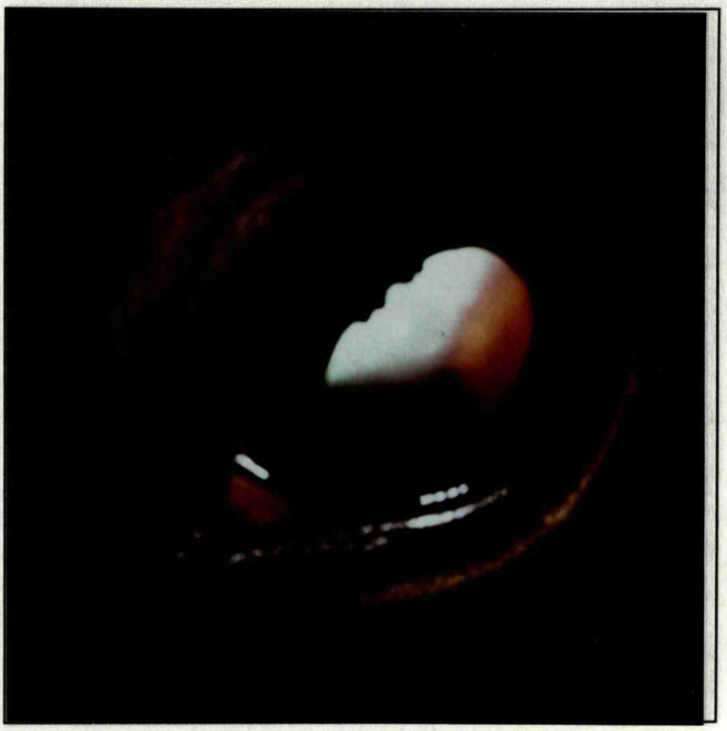
131b. Bay, normal, 12 hour old foal. Right eye of 131a.

132. Bay, normal, 31 hour foal. Right eye. The complete, thin, red hyaloid artery is seen running towards the camera upwards from the centre of the salmon-pink optic disc. The grey-brown non-tapetal fundus is also visible.

133. Bay, normal, 20 hour old foal. This view shows a complete, black, thin hyaloid artery running from the posterior capsule of the lens, immediately below the upper eyelid, and is highlighted against, and runs towards, the optic disc.

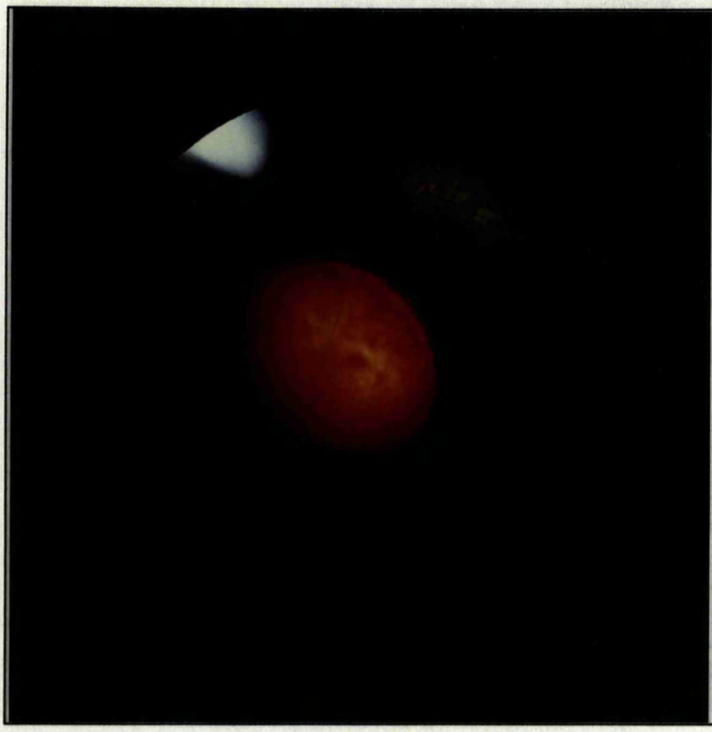


134. Bay, normal, 19½ hour old foal. A complete, normal diameter, red, hyaloid artery is seen running from the optic disc towards the lens.

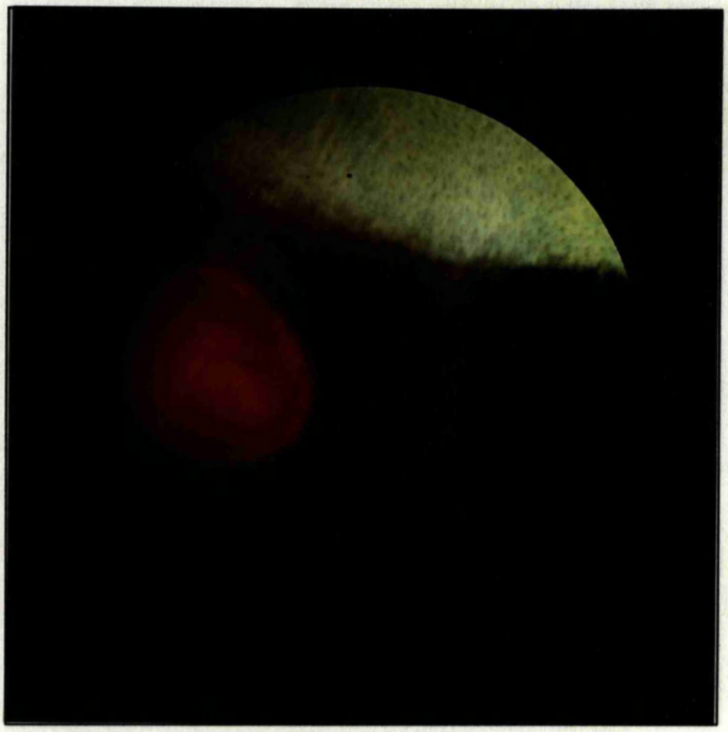


135. Bay, normal, 20 hour old foal. On the posterior capsule of the pupil there is a focal, mildly opaque area which is associated with a small, translucent hyaloid artery remnant.

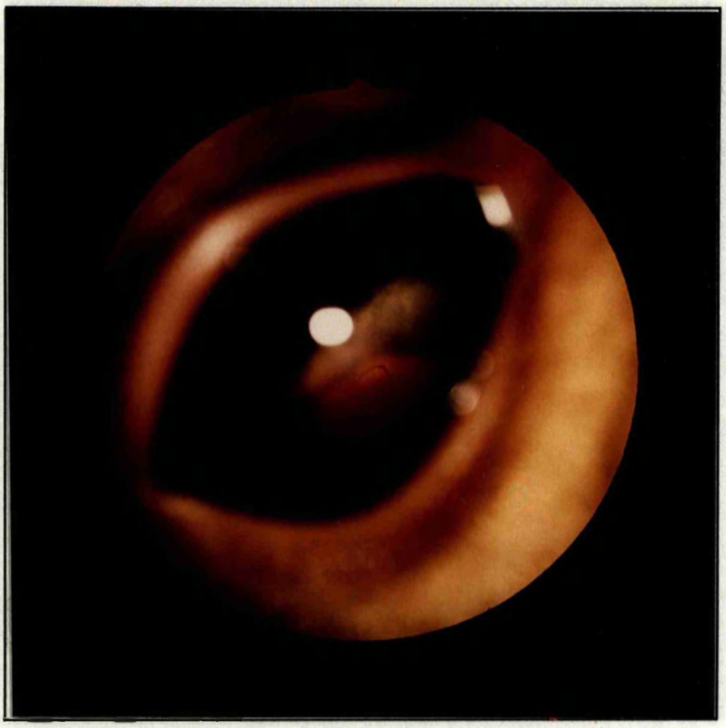
136. Bay-brown, normal, 16 hour old foal. A thin, translucent, floating hyaloid artery is seen running transversely across the equator of the pupil.



137. Bay-brown, normal, 16 hour old foal. This peripapillary view shows a normal-shaped pink optic disc with a slightly light centre and mid-ventral white rim. Very careful scrutiny reveals a thin straight line in the centre of the disc. This is a complete, thin, translucent hyaloid artery running from the disc towards the camera. Dorsal to the disc the dark grey-brown non-tapetal fundus is mildly depigmented and several straight, linear choroidal vessels are evident running towards the straight, normal border. The green yellow tapetal fundus has several blue spots visible which are probably end-on choroidal vessels.



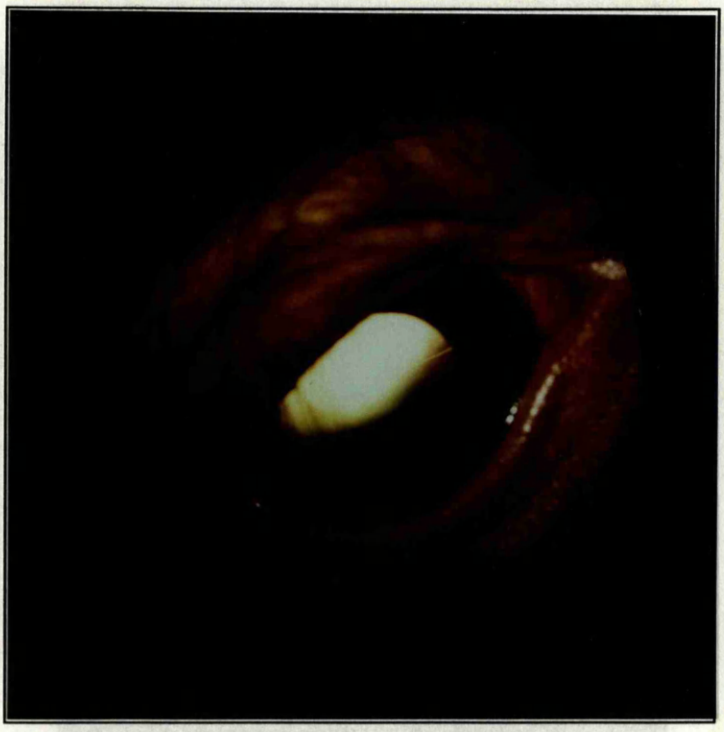
138. Bay, normal, 13 hour old foal. From the centre of the red-pink optic disc a red linear structure can be seen running towards the camera. This represents a complete, thin, red hyaloid artery. The dark brown non-tapetal fundus, normal straight border, and green yellow tapetal fundus are all seen clearly. The area dorsal to the disc has depigmentation, choroidal vessels and green streaking into the tapetal fundus. The lines running vertically across the photograph are due to the excessively long upper eyelid cilia obstructing the camera view.



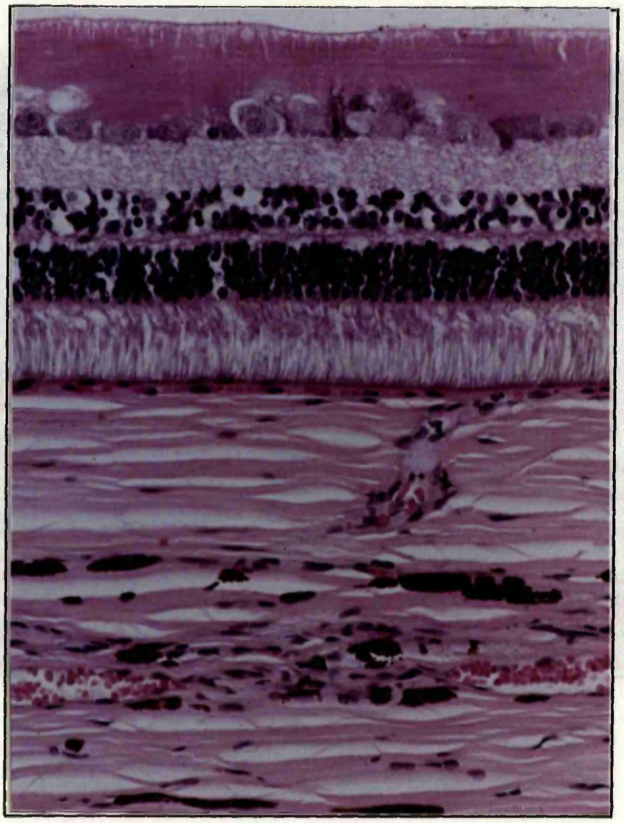
139. Chestnut, normal, 13 hour old foal. A normal, black, complete hyaloid artery is seen curving from the optic disc to the posterior lens. This was seen to move as the foal's head position shifted.

140. Bay, normal, 20 hour old foal. A normal diameter, complete, red, hyaloid artery is seen running towards the lens from the disc. This vessel appeared to float as the foal's head was moved.

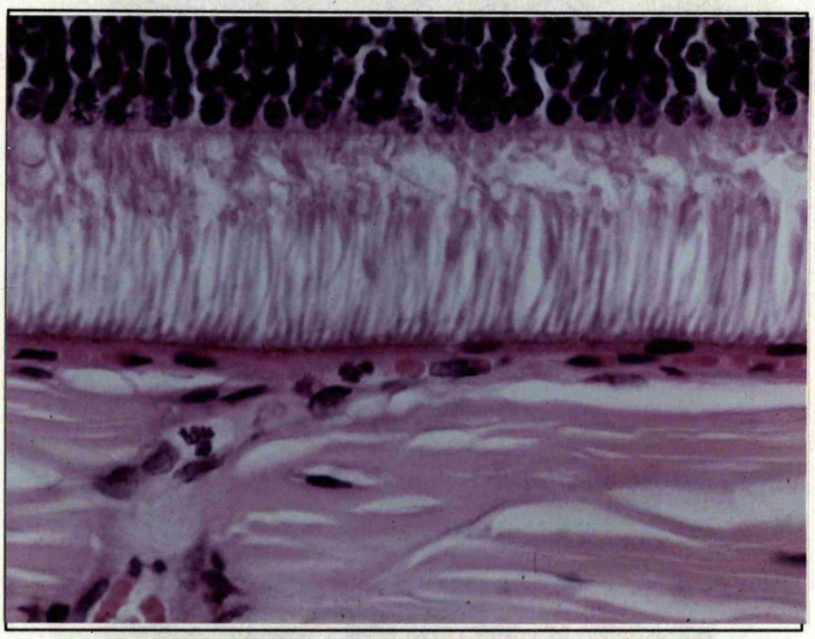
141. Chestnut, normal, 18½ hour old foal. The pale pink, normal-shaped optic disc has a light centre and border with a slight dorsal extension. In the centre is a fine straight line representing the thin, red, complete hyaloid artery. The retinal vessels are particularly obvious in the non-tapetal fundus near the atypical coloboma. Notice also the dorsal-to-disc depigmentation, ragged border and start of green-yellow tapetal fundus.



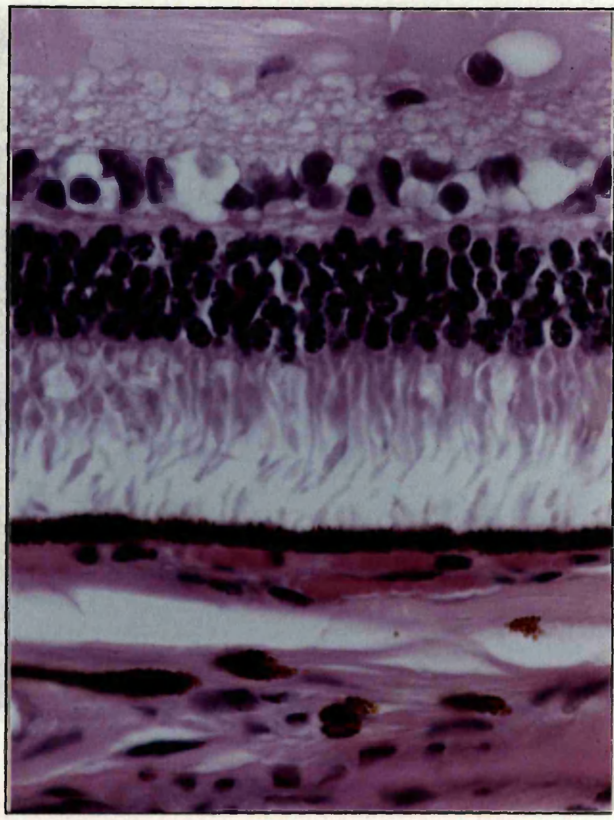
142. Chestnut, normal, 18 hour old foal. The very short and sparse lower cilia, and unpigmented lid margin are shown. The complete, thin, translucent hyaloid artery is seen running away from the lens in the nasal side of the pupil.



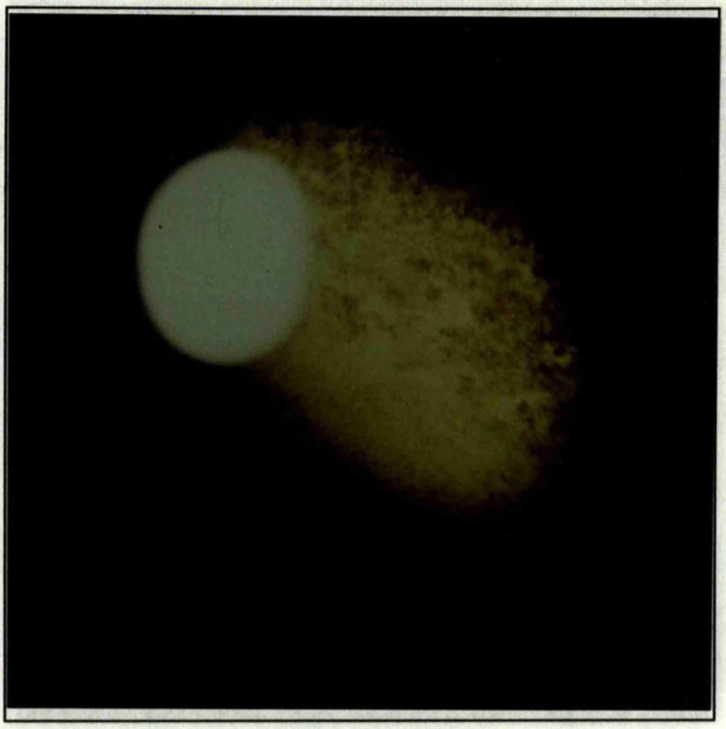
143. Photomicrograph of cross section through the tapetal fundus and choroid. Note in the upper part, the retina (see figure 28 for structure). The non-pigmented retinal pigment epithelium is in intimate contact with the vascular choriocapillaris. Immediately beneath this is the tapetum consisting of parallel orientated collagen fibrils. Note the large vessel passing through the tapetum towards the choriocapillaris and immediately beneath this the heavily pigmented suprachoroidea and lamina fusca.



144. Higher powered photomicrograph of cross section through the tapetal fundus and part of choroid. Note the non-pigmented retinal pigment epithelium in intimate contact with the photoreceptor layer of the retina. Immediately beneath is the vascular choriocapillaris and tapetum.

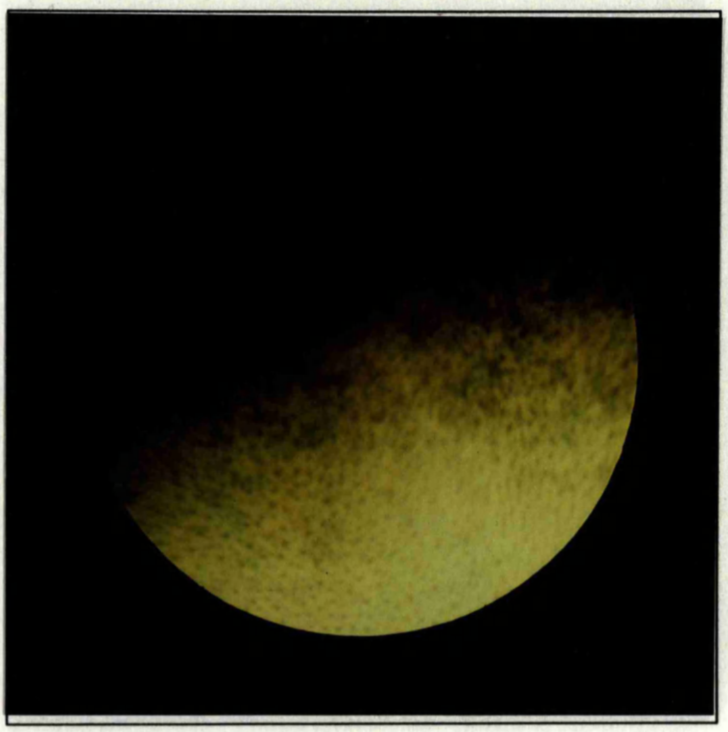


145. High powered photomicrograph of cross section through the non-tapetal fundus and choroid. Note the heavily pigmented retinal pigment epithelium and closely associated choriocapillaris. The tapetal layer is absent and the pigmented suprachoroidea is immediately below the choriocapillaris.



146. Chestnut, normal, 15 minute old foal. A view of the fundus showing extensive dorsal and peripheral pigment mottling and category 2 tapetal fundic colour (yellow, slight green periphery).

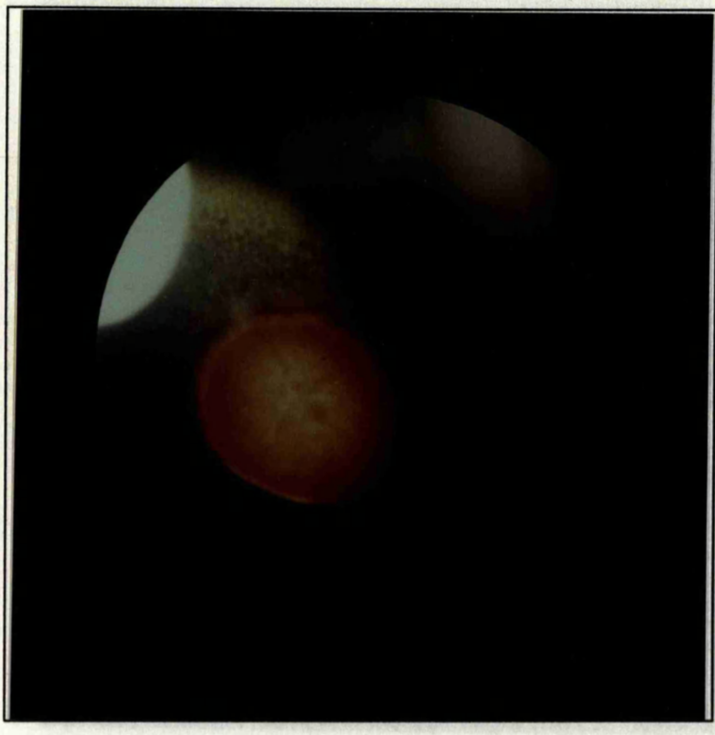
147. Chestnut, normal, 18 hour old foal. This peripapillary view shows a yellow green tapetal fundus with greenish Stars of Winslow, straight border and dark brown non-tapetal fundus with a considerable area of depigmentation dorsal to the optic disc. The disc is normal-shaped and pink, with a light centre and border, mid-ventral white rim, obvious retinal vessel pattern, and accumulation of pigment dorsally on the disc edge.



148. Chestnut, normal, 11 hour old foal. A yellow-green tapetal fundus showing uneven pigmentation in the dorsal part. The small dark dots are Stars of Winslow.

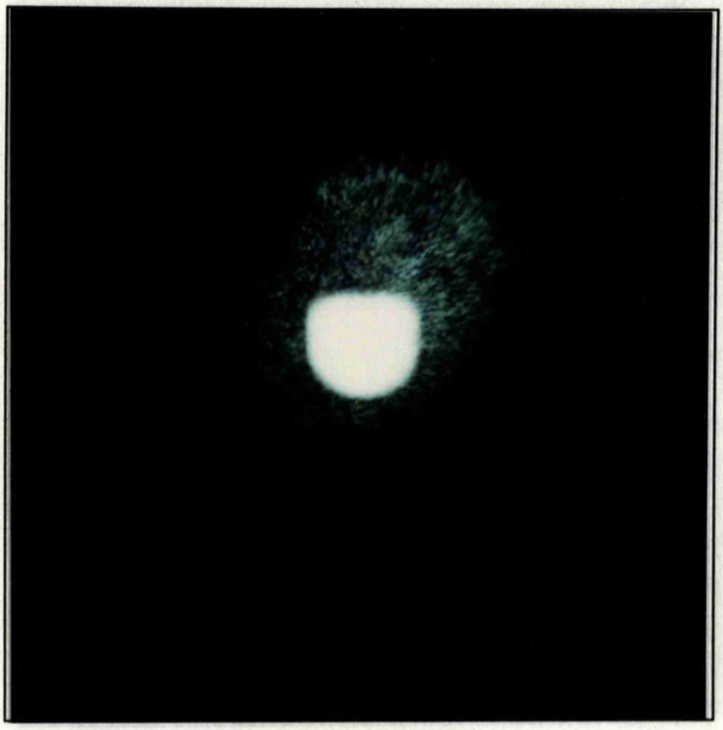
149. Adult, bay horse. This view shows a typical pale optic disc and retinal vessel pattern. To one side of the disc there is a large discrete area of partial loss of pigment (appears pink) immediately next to the border. Retinal vessels are still seen running through it and it is almost certainly a type of atypical coloboma. It is surrounded by a more generalised, but less severe, area of non-tapetal fundus depigmentation allowing choroidal and vortex veins to be distinguished as red-purple striations or dense spots.

150. Bay, normal, 59 hour old foal. This peripapillary fundic view shows a normal-shaped, salmon-pink, optic disc with light centre and dorsally, a thin light border. There is a small mid-ventral white rim and one tortuous retinal vessel on the disc. Dorsally, there is slight depigmentation of the non-tapetal fundus with a thin rim of pigment clumping adjacent to the disc dorso-nasally.

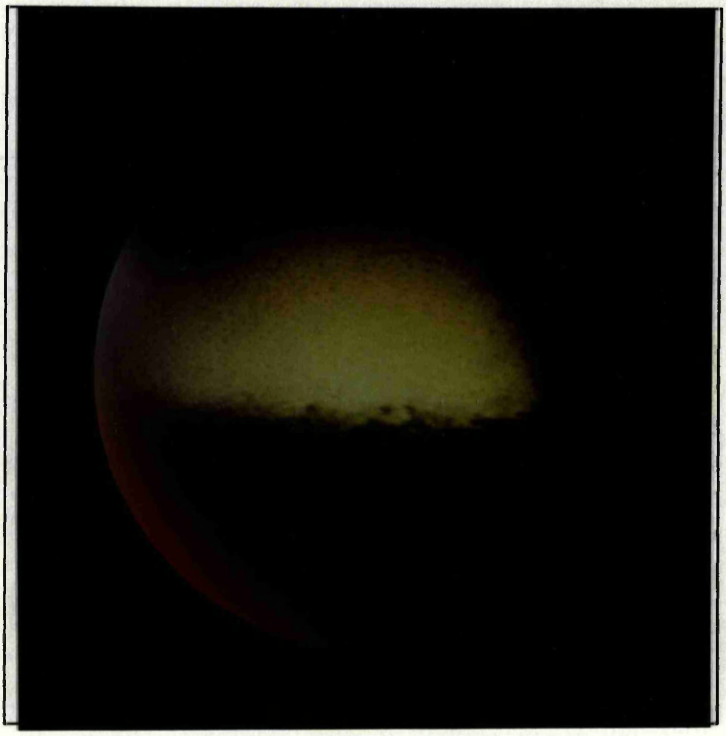


151. Grey, normal, 16½ hour old foal. This pink, nasally blunted, oval optic disc, has a mid-ventral white rim, light border and centre, and slight dorsal extension. The dorsal-to-disc area of the grey brown non-tapetal fundus is partially depigmented, with choroidal vessels visible and increased pigment deposits adjacent to the dorsal disc margin.

152. Bay, normal, 20 hour old foal. The view of the peripapillary region reveals a pale pink, normal optic disc with a light centre and border, and slightly irregular dorsal edge. There is one particularly prominent and tortuous retinal vessel running from well within the disc onto the non-tapetal fundus.



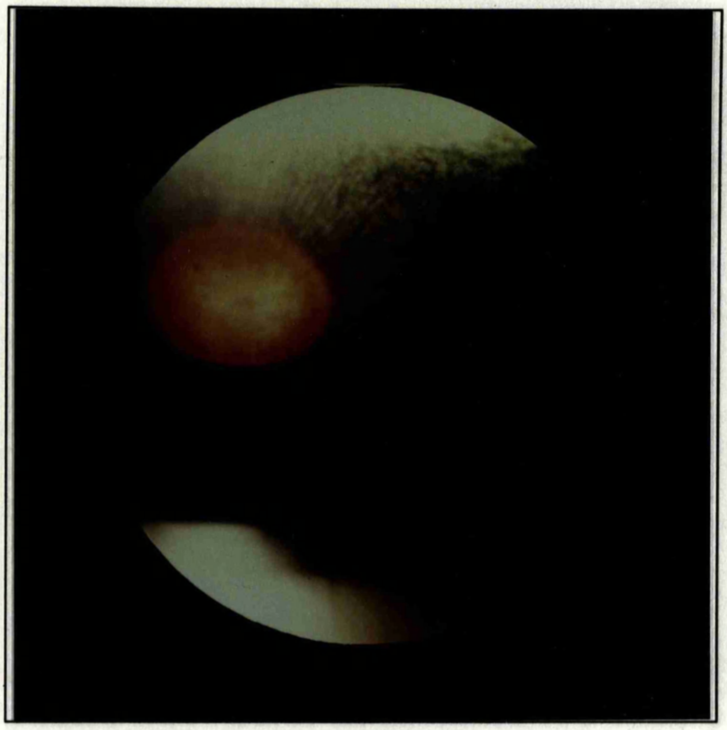
153. A dark grey, normal, neonatal foal. The mottled bluish-green dorsal tapetal fundus with prominent Stars of Winslow are seen in this restricted view.



154. Chestnut, normal, 15 hour old foal. This view of the fundus shows the yellow-green tapetal and dark grey-brown non-tapetal parts, separated by a distinct straight border. The Stars of Winslow are easily seen in the tapetal fundus.

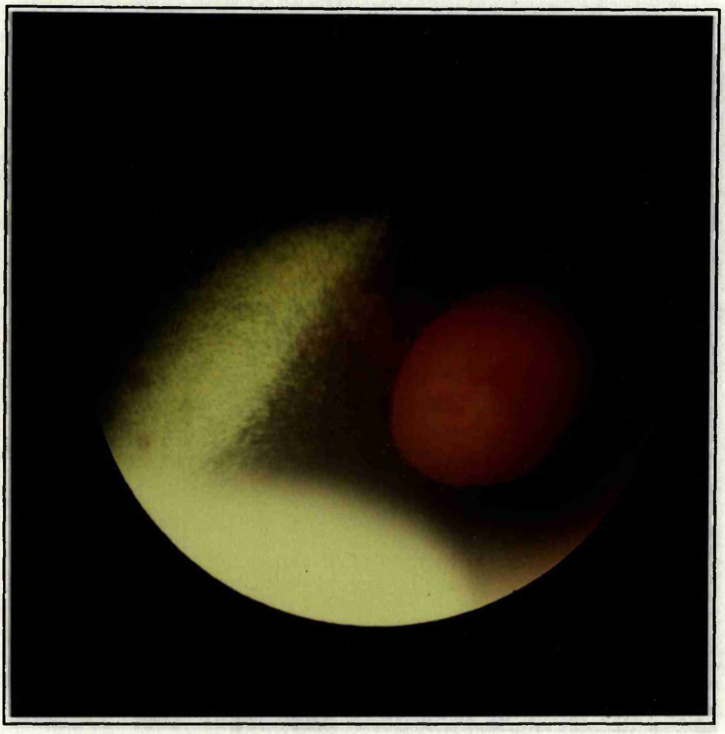
155. Bay, normal, 31 hour old foal. Right eye. Salmon-pink, optic disc with dorsal bulge and dorsal-to-disc depigmentation. Within this area are just visible reddish-purple parts of choroidal vessels. Note the straight, distinct border between tapetal and non-tapetal fundus.

156. Bay, normal, 60 hour old foal. This is a view of the non-tapetal fundus ventro-nasal to the optic disc. Note the ragged border and dark brown non-tapetal fundus.



157. Bay, normal, 28 hour old foal. A slightly smaller and rounder pink optic disc with light centre, with obvious retinal vessel pattern, especially in the area of depigmentation dorsal to the disc. Note also how the border between the two parts of the fundus almost disappears dorsal to the disc.

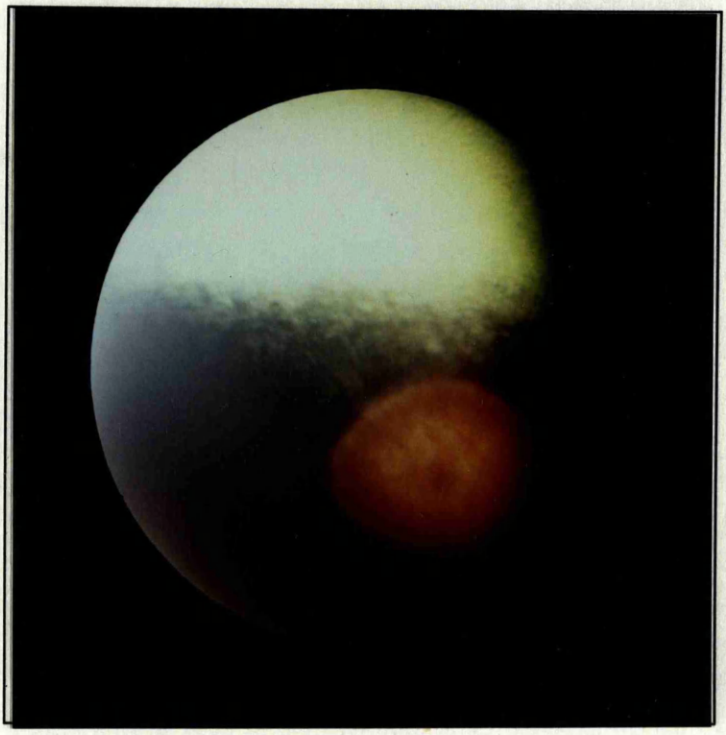
158. Bay, normal, neonatal foal. The temporal quadrant green-yellow tapetal fundus, which almost has a bluish tinge, is seen just dorsal to a distinct border with a dark, almost black non-tapetal fundus. Note the focal, slightly darker, areas of tapetal colouration scattered through the tapetal fundus which Latimer *et al* (1983) describes as tapetal islands.



159. Bay, normal, 6½ hour old foal. This peripapillary view of the left eye shows a pink to red-pink, normal-shaped optic disc which is very nearly homogenous, but with a slightly light centre. The dark brown non-tapetal fundus is very mildly depigmented dorsal to the disc, with a number of prominent red choroidal vessels in this area. Small splash and punctate retinal haemorrhages are seen dorsal to the disc in the yellow-green tapetal fundus.

160. Bay, normal, 60 hour old foal. This view of the peripapillary fundus shows a pink optic disc with light centre and border, and an irregular, almost triangular shape. The dorsal part of the disc shows a bulge which may be increased myelination. Dorsal to the disc there is loss of pigmentation of the non-tapetal fundus, with small areas of pigment clumping immediately adjacent to the dorso-nasal and ventral disc margin. Underlying choroidal vessels are just visible. To the dorso-nasal side of the disc are small areas of irregular depigmentation, possibly of a tapetal fundus colour. These may be tapetal islands as described by Latimer *et al* (1983). The tapetal fundus is yellow-green and shows prominent Stars of Winslow, especially peripherally.

161. Chestnut, normal, 15 hour old foal. This salmon-pink, slightly rounded optic disc has a light centre and dorsal border. The dorsal-to-disc area is depigmented with peripapillary pigment clumping.



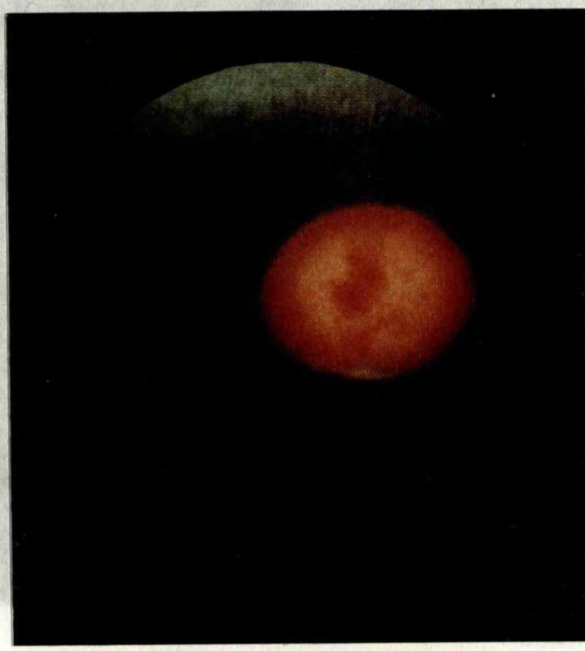
162. Bay, normal, 17 hour old foal. A pink, light centre and border, nasally blunted and larger than normal disc is seen in a dark grey-brown non-tapetal and yellow-green tapetal fundus. There is slight dorsal extension of the disc, mild dorsal-to-disc depigmentation, a small number of localised red choroidal vessels and a straight normal border. The Stars of Winslow are quite difficult to identify.

163. Chestnut, normal, 15 minute old foal. A red-pink, almost red, homogenous optic disc with irregular edge. Ventrally there are several areas where the disc appears to extend outwards around the retinal vessels.

164. Bay, normal, 13 hour old foal. A red-pink optic disc is seen with a light centre and border, small mid-ventral white rim and dorsal extension of disc margin. The dorsal-to-disc non-tapetal fundus is depigmented with slight evidence of red choroidal vessels. Note the normal retinal vessel pattern.

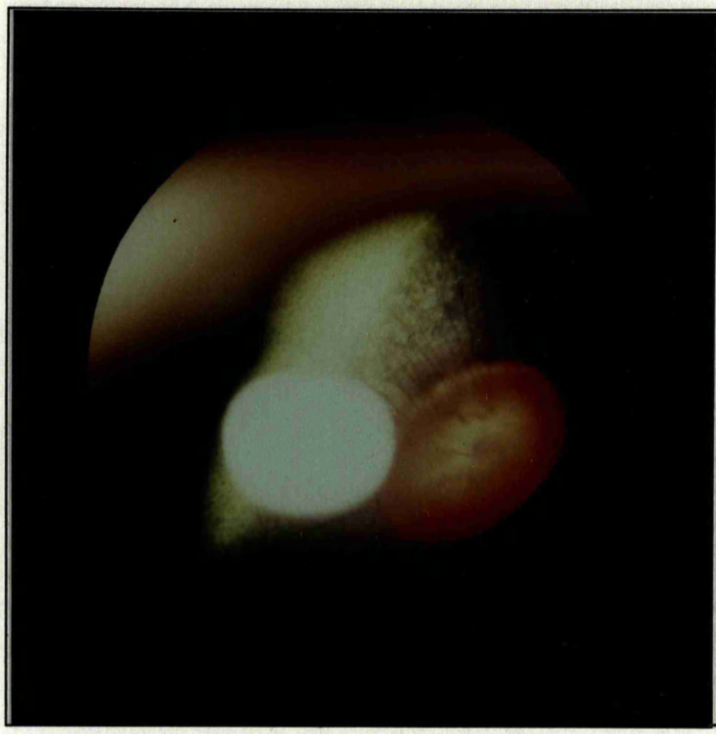
165. Bay, normal. 11 hour old foal. A view of the peripapillary area of the fundus showing a yellow-green tapetal and dark grey-brown non-tapetal fundus, separated by a straight normal border. The normal shaped, nearly red-pink optic disc has an almost homogenous appearance with a slightly lighter border and centre. The dorsal-to-disc area has a mild loss of pigment with accompanying red choroidal vessels. The retinal vessels are normal.

166. Bay, normal, 11 hour old foal. The right eye of this foal has a pink optic disc (compare figure 170 with red-pink disc) with a light centre and border.

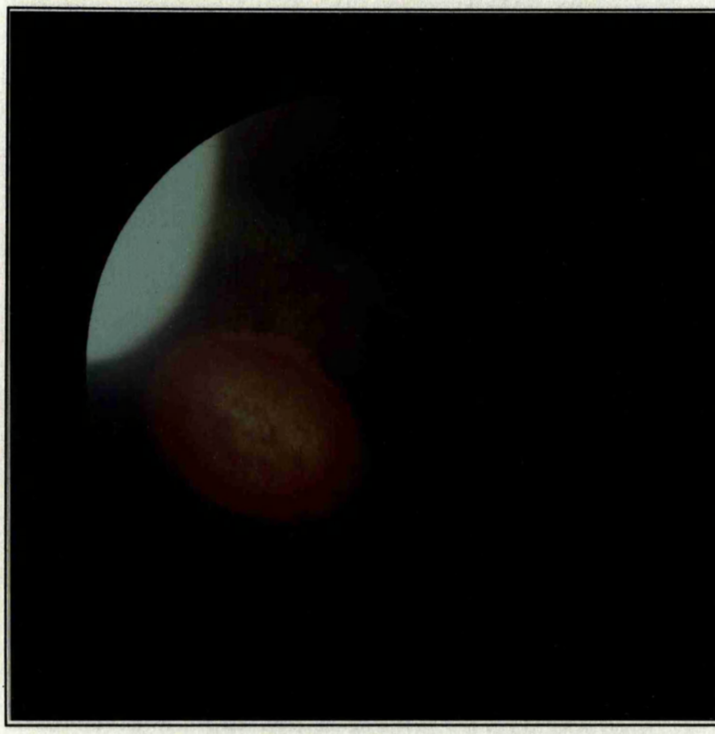


167. Dark grey, normal, 10½ hour old foal. Left eye. A slightly nasally blunted, oval, red-pink optic disc contains a single, large, splash-like, fresh, retinal haemorrhage centrally. Also present is a mid-ventral white rim to the disc, slight dorsal-to-disc depigmentation, dark brown-grey non-tapetal fundus, and green tapetal fundus.

168. Dark brown. normal, 14 hour old foal. A pale pink, large round optic disc with slight extension on one edge is seen in this peripapillary view. Note the orange-pink "streak" of dorsal-to-disc depigmentation running from the disc equator dorsally. There is slight pigment accumulation around the disc margin.



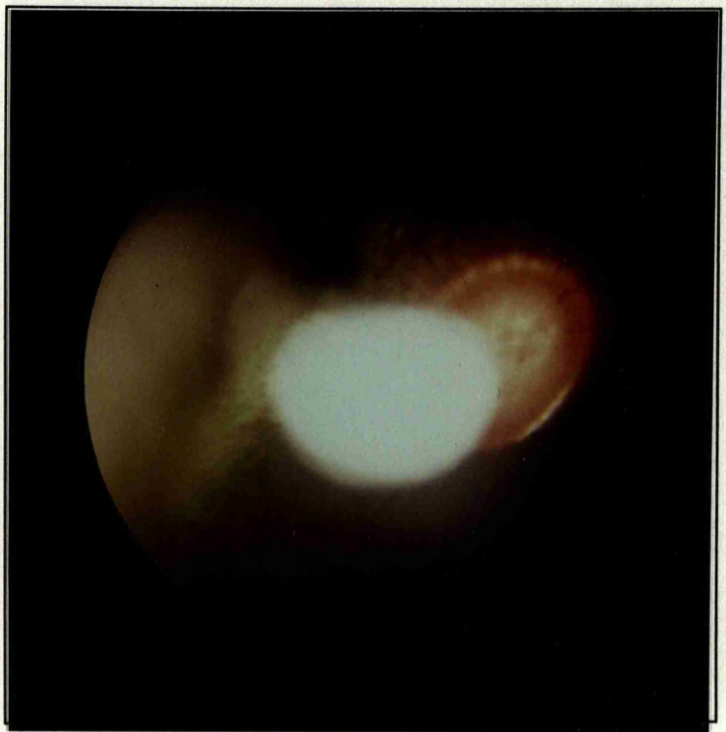
169. Chestnut, normal, 18 hour old foal. This peripapillary view is of the opposite eye to figure 147 and shows a flattened oval optic disc, especially ventrally, with pink colouration and light centre and border. Note the prominent intra-disc tortuous vessel.



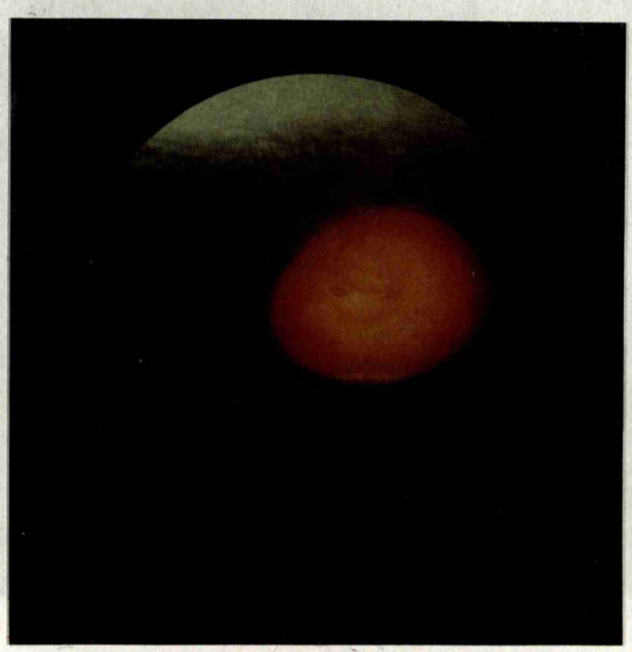
170. Bay, normal, 16 hour old foal. A peripapillary fundic view showing a nasally blunted, pale pink optic disc of normal size with a light centre and slight dorsal extension. There is mild dorsal-to-disc depigmentation and choroidal vessel appearance.

171. Bay, normal, 19½ hour old foal. This view shows a pale pink optic disc with a light centre and border and a flattened, almost notched, ventral border.

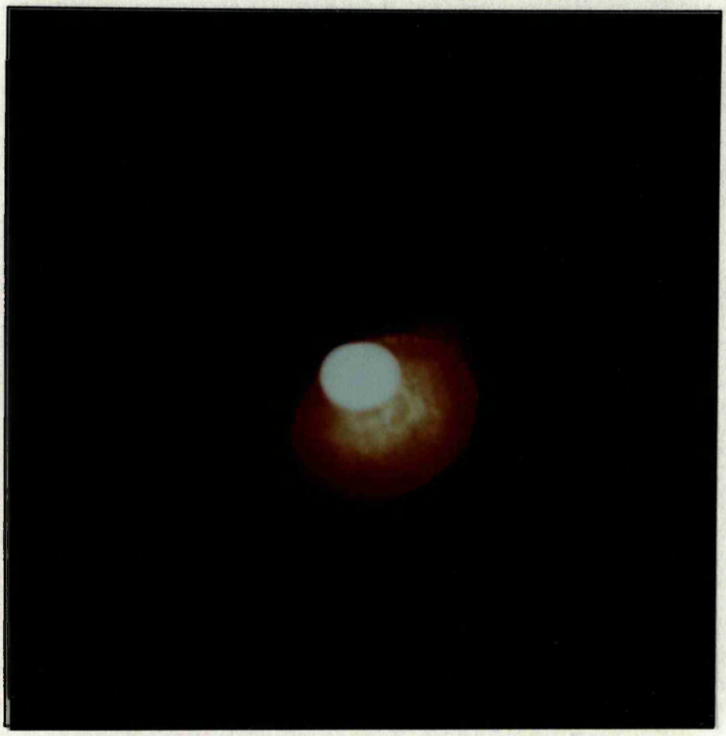
172. Chestnut, normal, 6 hour old foal. A pink, homogenous, normal shaped optic disc is seen at the edge of this view of the dark brown-grey non-tapetal fundus. The border, which was straight and normal, becomes more ragged as it approaches the disc, dorsal to which is an area of depigmentation. Within the non-tapetal fundus, just to the non disc side of the flash reflection, is a small, punctate, whitish, non-pigmented area, an atypical coloboma. The green-yellow tapetal fundus is just visible.



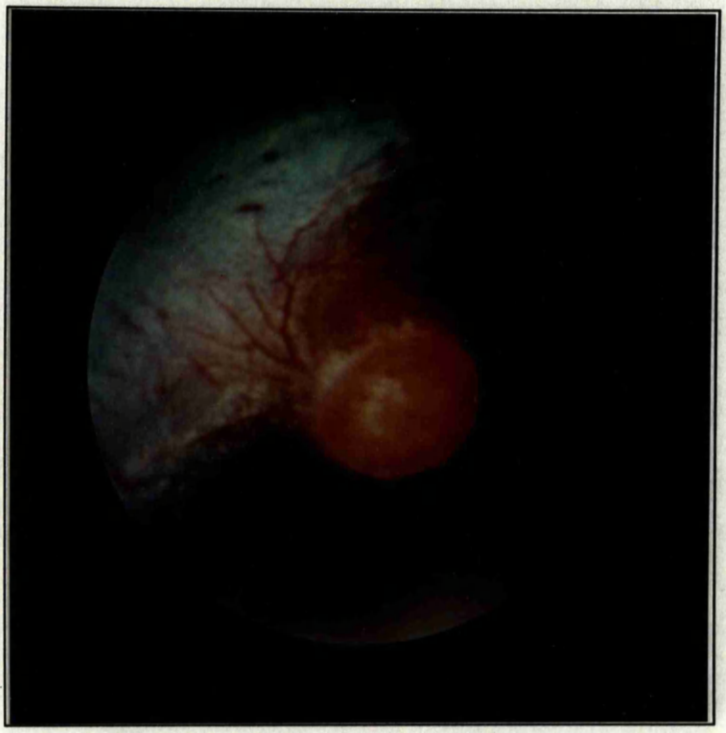
173. Grey, normal, 18 hour old foal. This view of the optic disc shows a mid ventral white rim, red-pink colouration, lighter centre and partial border, and enlarged retinal vessels ventro-temporally. This foal had retinal haemorrhages in the green-yellow tapetal fundus.



174. Dark grey, normal, 10½ hour old foal. Right eye. A slightly nasally blunted, oval, pink optic disc with mid-ventral white rim, light centre and slight dorsal extension, does not contain any haemorrhages in this eye. The retinal pigment epithelium depigmentation is more obvious in this eye, both dorsal to the optic disc and peripherally.

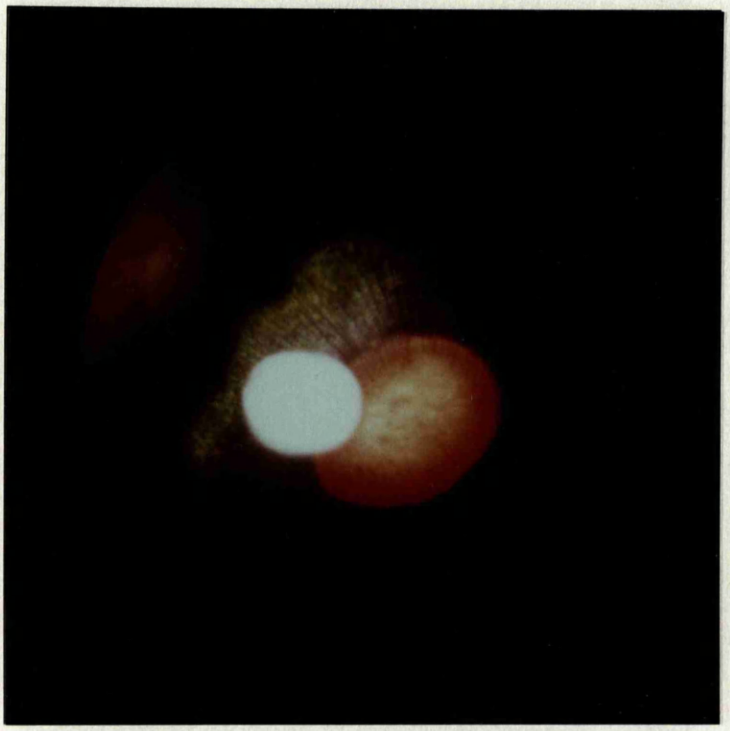


175. Bay, normal, 12 hour old foal. The normal shaped, red-pink optic disc with light centre and border has, on the temporal border and running into the non tapetal fundus, a number retinal blood vessels with increased tortuosity.



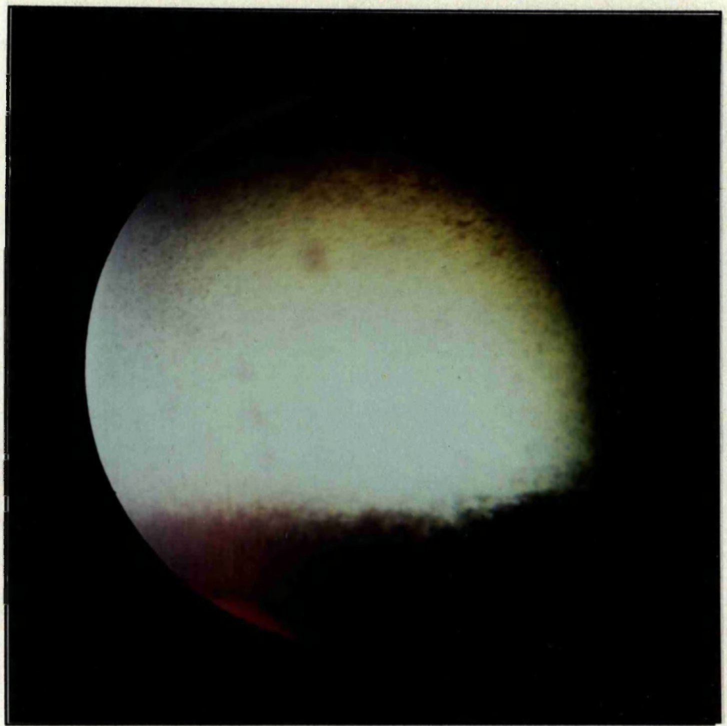
176. Bay, normal, 60 hour old foal. A peripapillary view of this foal showing the blue-green tapetal fundus and choroidal vessels, including a few purple spots representing end-on vessels. The lack of retinal vesels is clearly demonstrated.

177. Bay, normal, 5 day old foal. Many widespread, mauve, resolving, mixed pattern retinal haemorrhages are seen in the green-blue tapetal fundus. Notice the way the centre of the haemorrhages are paler and the edges are diffuse and indistinct. The optic disc in this older foal is of a more normal adult colour and appearance (pale pink, light centre and border, mid-ventral white rim, normal oval shape), but on one edge, with careful examination, two streak haemorrhages immediately around two retinal vessels can just be seen.

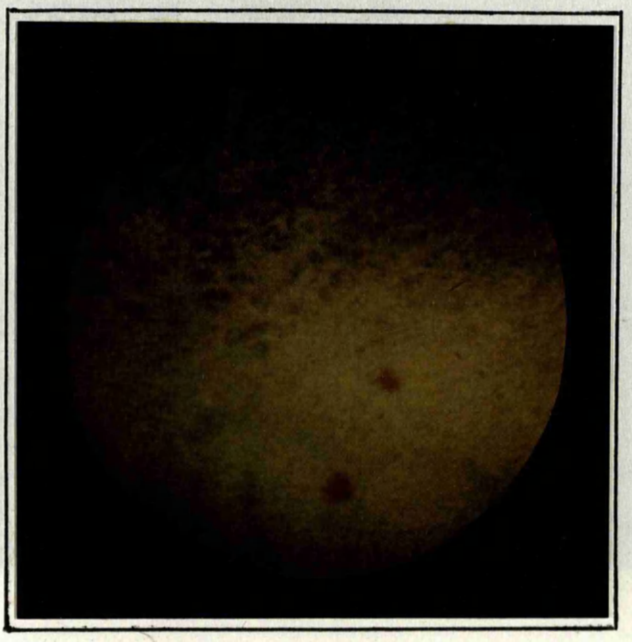


178. Chestnut, normal, 6 hour old foal. This peripapillary view shows a normal shaped, pink disc with slightly light centre. The retinal vessel pattern is very obvious in the dorsal-to-disc depigmented region of the non-tapetal fundus, as straight red lines radiating outwards just over one disc's diameter. Ventrally the disc appears to extend out along the line of the retinal vessels giving an almost "frilly" appearance.

179. Grey, normal, 18 hour old foal. A view of the fundus of the left eye showing approximately 10 small splash retinal haemorrhages in the tapetal area. They are of a reddish-purple colour, show early resolution and, although widespread, are concentrated more temporally. Note the yellow tapetal fundus and dorsal pigment mottling, normal border region and dark brown non-tapetal fundus.

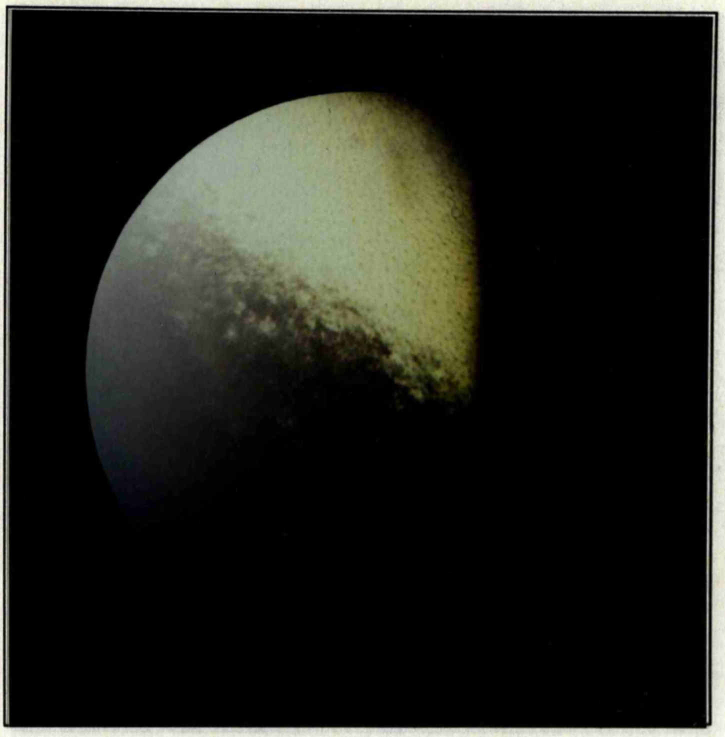


180. Chestnut, normal, 59 hour old foal. The left eye of a foal showing the resolution of the dorsal-to-disc retinal haemorrhages (compare figure 193). The green-yellow tapetal fundus contains 4 mauve, resolving retinal haemorrhages with diffuse edges, making them more difficult to detect, in a discrete area dorsal to the optic disc. Note also the dorsal tapetal fundus dark brown mottling, the distinct border with the dark brown-grey non-tapetal fundus, and the area just dorsal to the optic disc which shows depigmentation and overall reddish-brown colouration.



181. Chestnut, normal, 2 day old foal. 2 punctate and 1 small splash, acute, red retinal haemorrhages are seen in the upper dorsal area above the optic disc in the tapetal fundus. Note also the predominantly yellow tapetal fundus with occasional green spots, and dark brown mottling of the dorsal area.

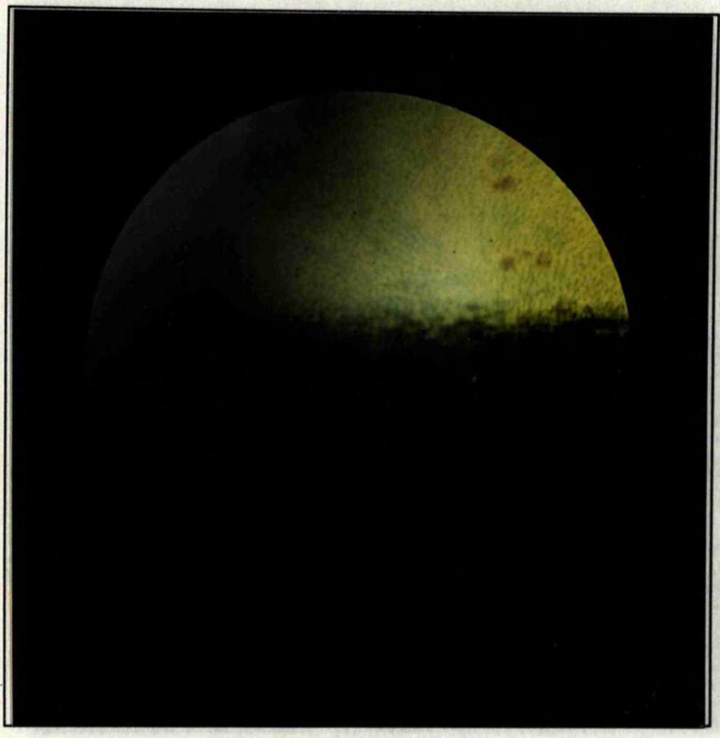
182. Bay, normal, neonatal foal. The green-yellow tapetal fundus in the nasal quadrant is bounded dorsally by a mottled edge of dark pigment, and ventrally by the distinct border with the dark grey-brown non-tapetal fundus.



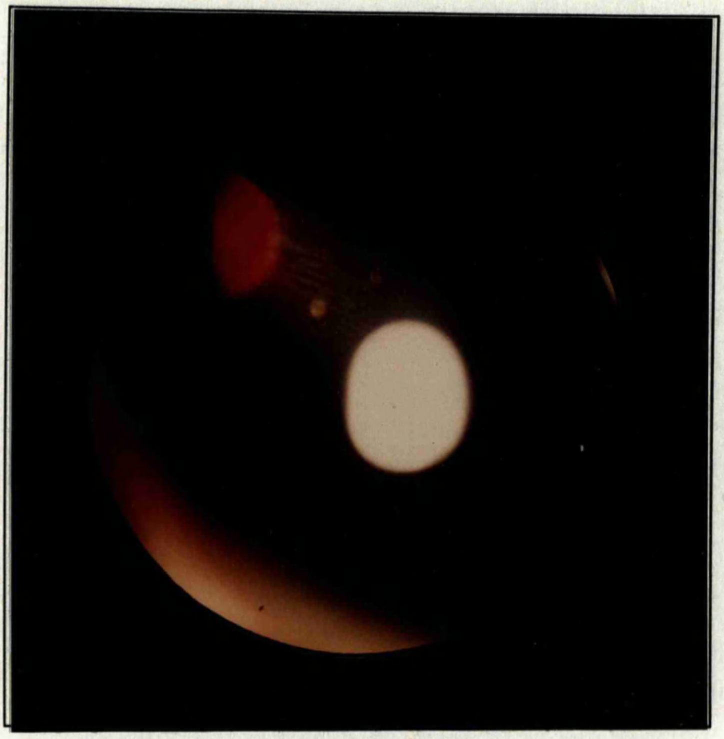
183. Bay, Normal 60 hour old foal. This view shows the ragged border between the tapetal and non-tapetal fundus. There are obvious foci of depigmentation just below the border and for some considerable distance ventrally into the dark brown non-tapetal fundus.

184. Bay-brown, normal, 15 minute old foal. A dark brown-grey non-tapetal fundus is seen to one side of the optic disc. The border is slightly ragged and appears to dip towards the disc. The yellow-green tapetal fundus extends into the dorsal-to-disc area.

185. Dark brown, normal, 14 hour old foal. A small, ragged edge, white, atypical coloboma is seen at the border of the tapetal/non-tapetal fundus just temporal to the choroidal "streak" / dorsal-to-disc depigmented area.

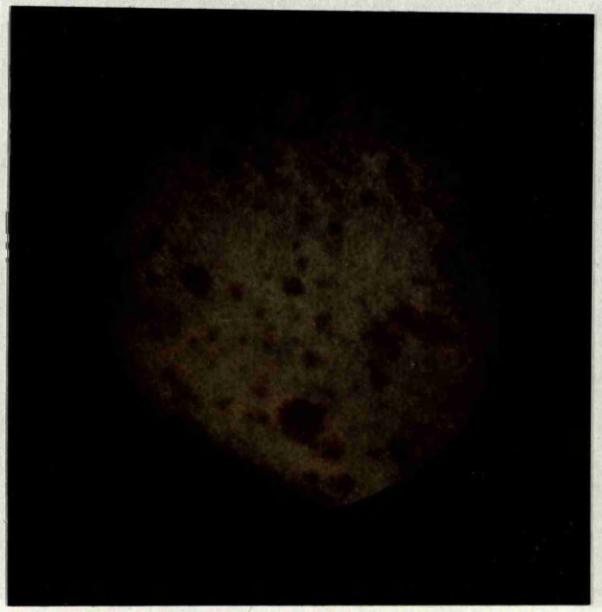


186. Bay, normal, 6½ hour old foal. This view of the right eye shows the nasal region of the border area with 6 early resolving, small, splash, red-purple retinal haemorrhages. These were part of a large number (>10) mixed, punctate and splash haemorrhages evident only on the nasal side of the tapetal fundus. The straight normal border, dark brown non-tapetal and yellow-green tapetal fundi, are also visible.

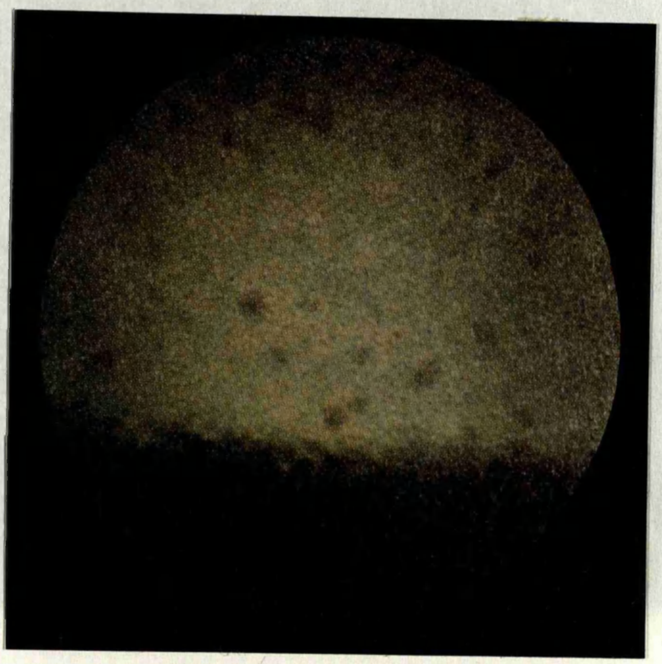


187. Chestnut, normal, 18½ hour old foal. At the level of the ventral half of the disc and on its nasal side are 4 unpigmented, small, round areas, previously described as atypical colobomas. All are within one disc's diameter of the disc and have retinal vessels running through them. The dorsal and largest area has the whitest colour suggesting the greatest degree of depigmentation.

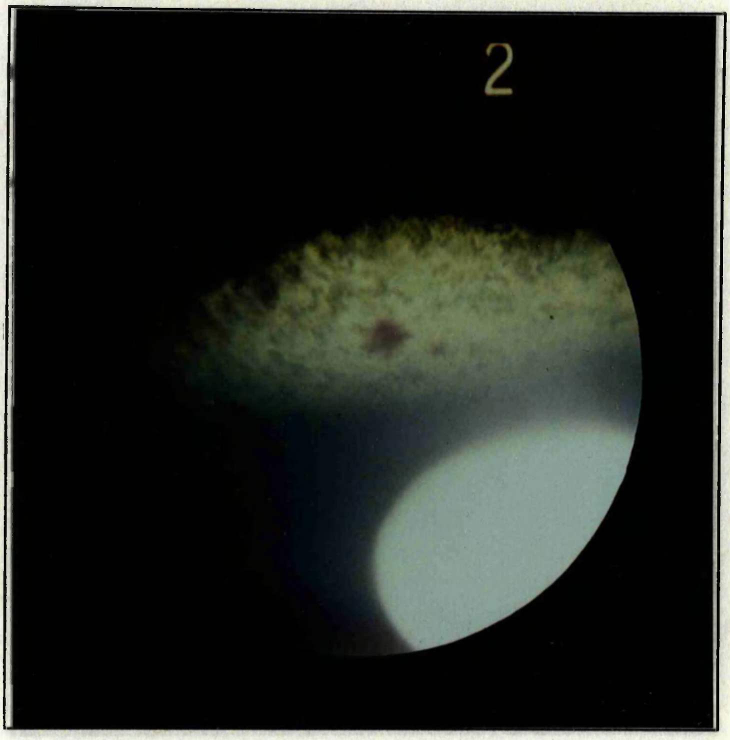
188. Bay, normal 60 hour old foal. This fundic view shows marked peripapillary choroidal and retinal pigment epithelium degeneration with obvious choroidal vessels especially dorsal to the disc. The pale pink optic disc is of normal shape and size, with a light centre and border, and ragged dorsal extension. Retinal vessels are decreased in number, although a few thickened ones are present on the temporal equator. Two focal whitish lesions are present ventral and nasal to the disc in the non-tapetal fundus. Notice the overall greyish appearance of the non-tapetal fundus.



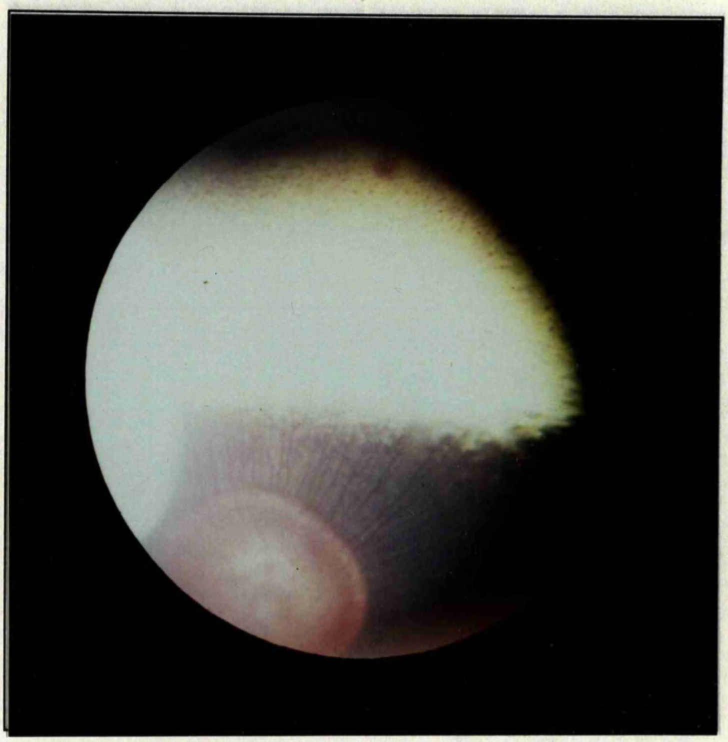
189. Bay, normal, 1 day old foal. Multiple, punctate, small and large splash-like, acute retinal haemorrhages are widespread in the green-blue tapetal fundus of this foal.



190. Bay, normal, 4 day old foal. Multiple, widespread, resolving, punctate retinal haemorrhages are seen in this green-yellow tapetal fundus particularly just dorsal to the border with the non-tapetal fundus.

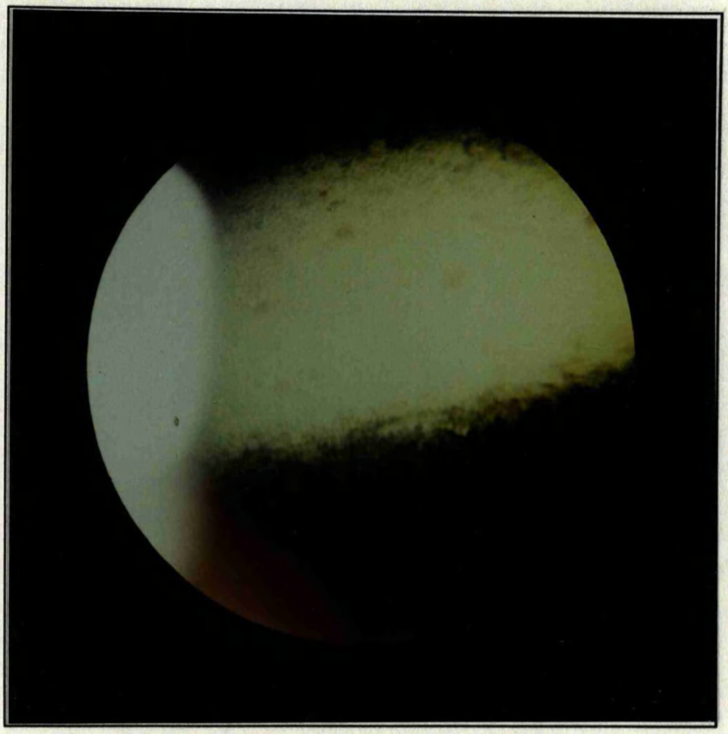


191. Bay, normal, 6½ hour old foal. This view of the left eye (see figure 186) shows mixed punctate and large splash, red-purple, early resolving, retinal haemorrhages in the dorsal tapetal fundus where there is dark brown pigment mottling. These haemorrhages were part of a group of between 6 and 10 that were localised in an area dorsal to the disc.



192. Chestnut, normal, 11 hour old foal. A single, small, splash-like retinal haemorrhage is present dorsal to the disc in the right eye. It is already purplish and in the early stages of resolution. The retinal vessel pattern is especially obvious dorsal to the disc.

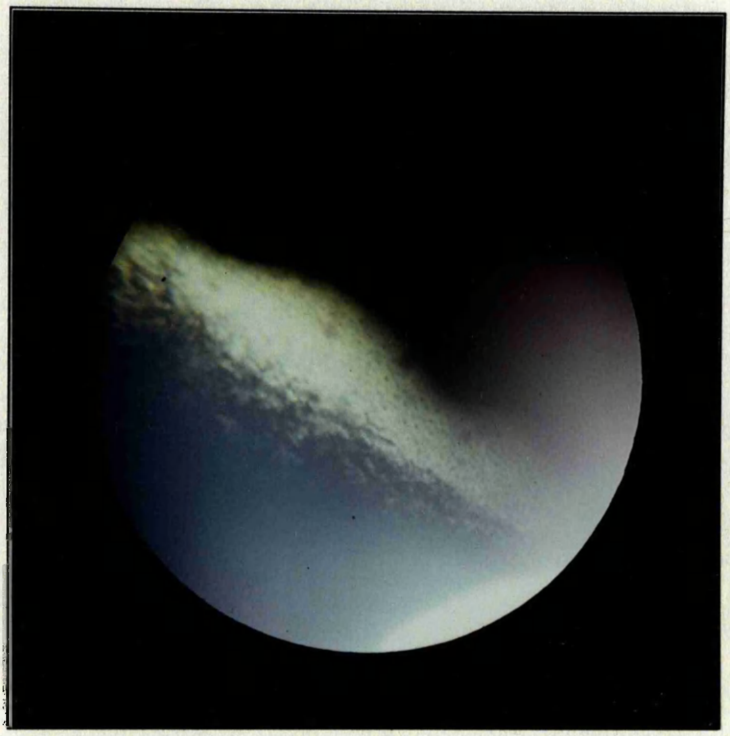
193. Chestnut, normal, 11 hour old foal. A ragged border is present between the green-yellow tapetal and dark grey-brown non-tapetal fundus. Some of the widespread retinal haemorrhages (between 15-20 in total) are present in the tapetal fundus of the left eye. These are reddish-purple and of a mixed pattern, including one large splash type.



194. Bay, normal, 6½ hour old foal. This overexposed view shows the nasal region of the fundus of the right eye, and the large number of mixed punctate and splash retinal haemorrhages throughout the tapetal area.

195. Chestnut, normal, 59 hour old foal. The right eye of a foal with widespread, mixed pattern, resolving retinal haemorrhages (compare figure 193). This limited view of the tapetal fundus just above the border shows decreased numbers of haemorrhageswith more diffuse edges. Those visible appear larger, are now mauve, and are more difficult to detect (see also left eye figure 180).

196. Gross specimen of normal posterior segment of adult equine eye. The section is cut transversely just behind the lens. The grey mist-like appearance over the fundus is the partially detached retina. Note the pink, irregular oval optic disc situated just below the border between the green tapetal and dark brown non-tapetal fundi. The dorsal and peripheral pigment mottling in the tapetal fundus is obvious. (section courtesy of J. Mould).

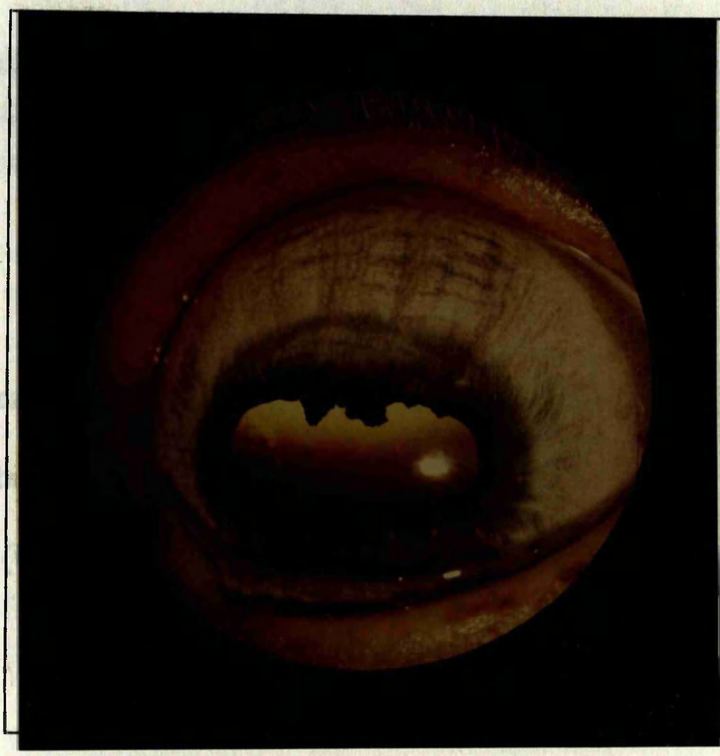


197. Chestnut, normal, 11 hour old foal. A ragged border between the green-yellow tapetal and dark grey-brown non-tapetal fundus is clearly seen. Note some of the widespread retinal haemorrhages present in the tapetal fundus (see figure 193).

198. Adult bay horse. These red-purple spots over the green-blue tapetal fundus are end-on choroidal vessels and should not be confused with retinal haemorrhages when seen in neonatal foals.

199. Adult bay horse. The vortex vein striations are clearly seen in the grey-brown non-tapetal fundus.

200. Adult riding pony with a history of a sudden onset of bilateral blindness following a fall and head trauma. Note the very pale optic disc, almost complete lack of retinal vessels and peripapillary/diffuse choroidal and RPE degeneration.



201. Heterochromia iridis is seen in this palomino pony. Notice the variation in colour as the iris approaches the pupillary margin. The pupil is a typical adult shape and size in ambient light.

APPENDIX 1.

Specially designed form used to record the standardised examination of each individual foal. Words and diagrams were used as appropiate. Repeat examinations each had additional new forms.

OPHTHALMIC EXAMINATION FORM.

General History

Breeding	Dam		Sire	
Breed (U.K./N.Z.)				
Foal	sex	size	colour	
	behaviour			
	time to stand		time to suck	
Foaling	time	date	number	
	behaviour			
Pregnancy				
Examination	time	date		

Ophthalmic Examination

Vision				
Reflexes	menace		PLR	consensual
	direct		rapidity	
	blink		palpebral	
Orbit	size		symmetry	
	strabismus		other	
Eyelid			length	density
cilia	upper			
	lower			
vibrissae	upper			
	lower			

abnormality
third eyelid size colouration

Conjunctivae R L

bulbar
palpebral

Cornea

shape size opacity
scleral shelf pectinate lines

Sclera R L

Iris

colour
appearance
pupillary size
shape
corpora nigra
dorsal
ventral
size
shape
per. pup. mem.
abnormalities

Lens

suture patterns
hyaloid system
other

Vitreous

Fundus

optic disc
retinal vessels
retinal haemorrhages

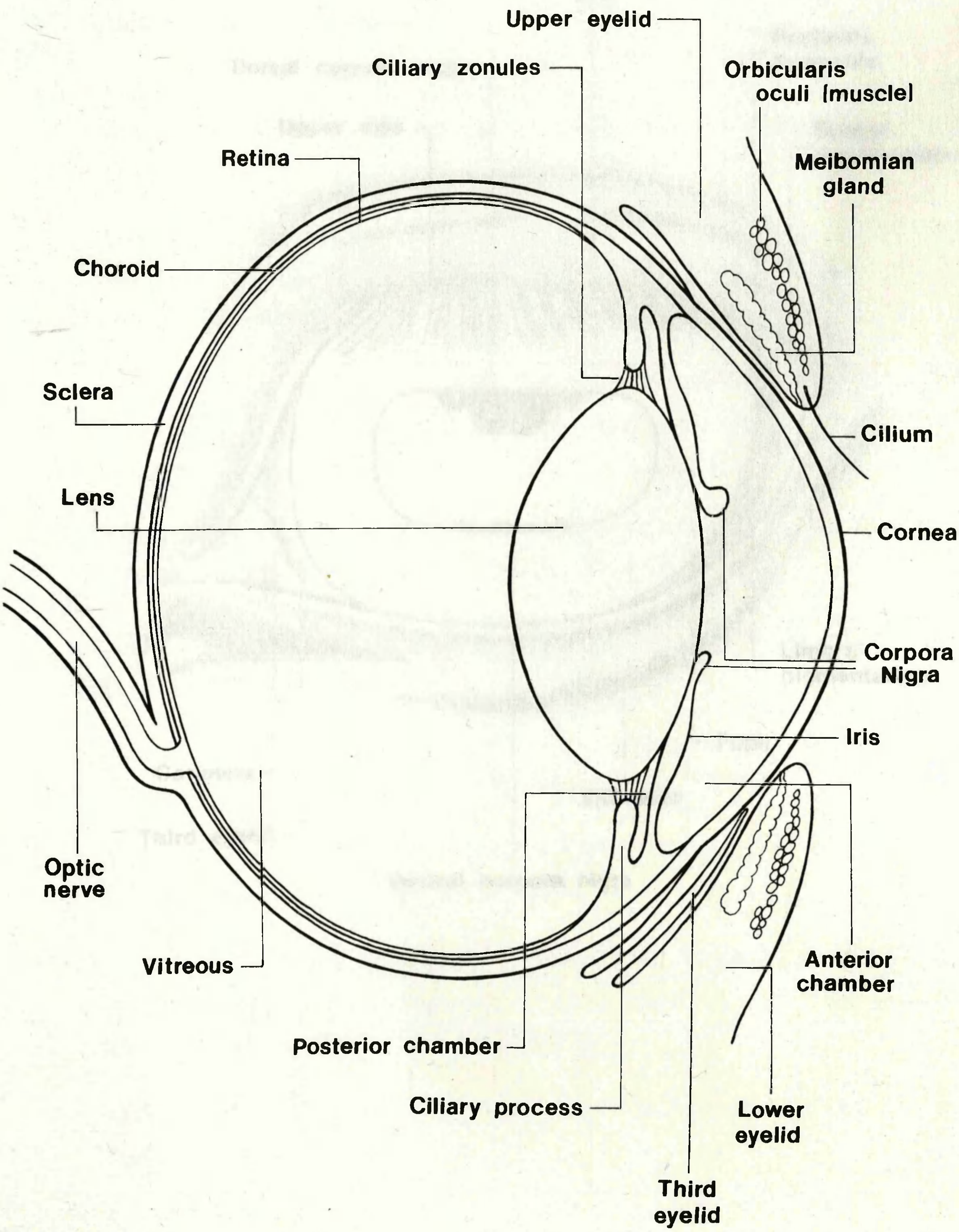
tapetal fundus

---------------------------------- border

non-tapetal fundus

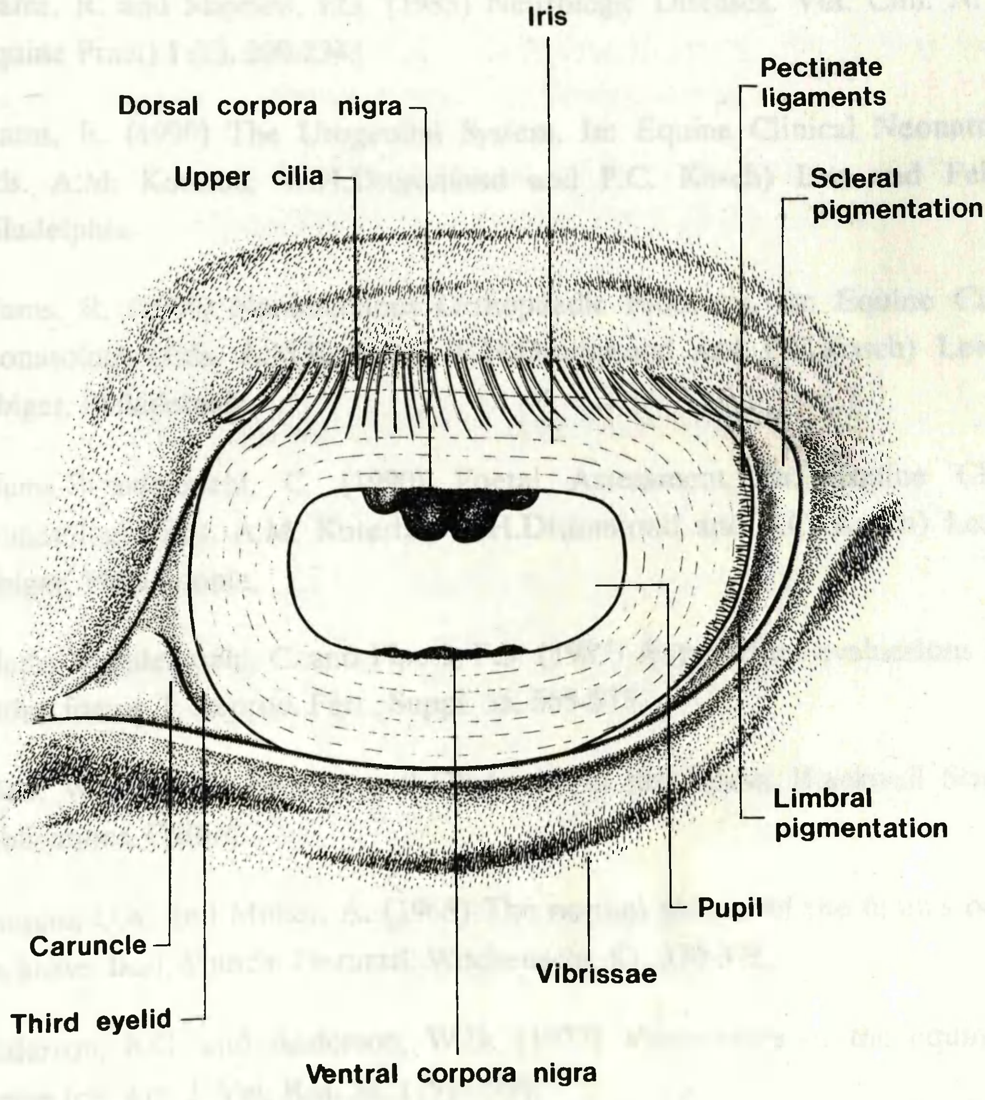
APPENDIX 2.

Diagram of a sagittal section of an equine eye detailing some of the anatomical structures and terms used in Appendix 1 (after Blogg, 1985).



APPENDIX 3

Diagram of the anterior aspect of the equine eye showing some of the anatomical structures and terms used in Appendix 1 (after Blogg, 1985).



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