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The Orbit and Extrinsic Muscles of the Eye of the European Bison, *Bison bonasus* (Linnaeus 1758)

Oczodół i mięśnie zewnętrzne gałki ocznej żubra, *Bison bonasus* (Linnaeus 1758)

Bisoniana IX.

[With 10 Figs. and 1 Table]

I. INTRODUCTION

This work is a part of an intended monograph on the organ of vision of the European bison. Before describing the extrinsic muscles of the eye I shall undertake a short description of the orbit.

The orbit of ruminants has been described mainly in manuals. Moreover Nussbaum (1902) mention the orbit of the sheep and Krysiak (1951) that of the European bison. The periorbita and the *m. orbitalis* have been investigated by numerous authors, by Bonnet (1841), Benz (1841), Groyer (1902) among others.

Müller (1858) investigated the *m. orbitalis* mentioned above and determined in a definitive manner its muscular character in mammals. Groyer (l.c.) described it with great accuracy in animals.

The extrinsic muscles of the eye has been investigated by many scientists: Nussbaum (1893, 1902), Corning (1902), Fleischer (1907), Cords (1924), Knutsson (1928) and many others.

Literature concerning the problem of innervation of the extrinsic muscles of the eye is especially abundant and very often contradictory in its results. The innervation of the *m. retractor bulbi* is presented in a different manner by sundry research workers. Two groups can be distinguished in those that are known to me. Nussbaum (1893), Corning (1902), Cords (1924), Frank (1949), Klimow & Akajewski (1960) belong to the first group, which maintains that *m. retractor bulbi* is innervated only by the abducent nerve. The second group of investigators: Du Bois-Reymond (1907), Fleischer (1907), Martin (1912), Ellenberger and Baum (1943) are of the opinion that the fibres of the oculo-motor nerve and of the abducent nerve innervate jointly the *m. retractor bulbi*. After Frank (l.c.) whose investigations were published relatively recently, in 1949, and who studied the problem thoroughly, only the 6th cranial nerve innervates the *m. retractor bulbi*.

Murat & Rupassow (1937) demonstrated by way of experiment the existence of a double kinetic innervation of some extrinsic muscles of the eye.

The sensitive innervation of extrinsic muscles of the eye is not sufficiently explained as yet, in spite of the existence of many publications treating this subject. Retzius (1892) was the first to notice the so-called atypical motorial terminations in the extrinsic muscles of the eye. These terminations were classified by Huber (1899) as belonging to the sensory category. Similar sensory terminations were found in animals by Crevatin (1901, 1902) and Dogiel (1906). Sherrington (1897) described the course of sensory fibres which are situated (in his opinion) in the stems of cranial nerves III, IV and VI, and ramify near the motorial branches. Boeke (1927), however, proved, on the basis of morphology and experiment, that these fibres belong to the sympathetic system and proceed from the anterior cervical ganglion. Wollard (1931) and Hines (1931) are of the same opinion.

Sensory innervation of the muscles mentioned above is not investigated thoroughly in domestic animals; general statements only indicate the origin of sensory fibres. Different scientists present this problem in a fragmentary manner. Thus Nussbaum (1902) considers as being sensorily innervated only three straight muscles of the eye *(dorsalis, ventralis, temporalis)* into which the sensory branches penetrate on the external surface, and the motorial branches on the internal surface of these muscles. This author maintains that the sensory branches derive from the trigeminal nerve and run in a single stem witht the motorial nerves. After Ellenberger & Baum (l.c.) sensory branches of the cow pass in two tracts: the ophtalmic nerve and the maxillary one. These authors give no precision as to the muscles to which separate tracts lead, beyond noting the junction of the zygomatic nerve with the oculo-motor nerve. Similarly, Martin (1938) and Rohen (1958) state that the extrinsic muscles of the eye receive sensory fibres from the trigeminal nerve. Schachtschabel (1908) and Klimow & Akajewski (l.c.) mention that the naso-ciliary nerve sends out a branch to the *m. rectus bulbi nasalis* and to the *m. retractor bulbi*.

It is worth mentioning that the sensory innervation as well as the sensory terminations of the extrinsic muscles of the eye play a very important role in the involuntary motorial correlation of both eyeballs.

B o e k e (1913, 1937) and S u n a g a (1927) studied the innervation of the autonomic nervous system of the extrinsic muscles of the eye.

II. MATERIAL AND METHOD

I investigated the cadavers of ten European bisons of different age and sex. When studying the orbit, I used as additional material 35 craniums of European bisons from the Centre for the Research on the European bison in Warsaw. Data concerning the date of birth of the European bisons are as in table 1.

Table 1.
Material.

Pedigree book No.	Name	Sex	Age rounded up to half a month		
575	Plato	♂	17 years	4 months	
785	Pluszcz	♂	10 „	5 „	
824	Plater	♂	7 „	$2^1/_2$ „	
858	Tatra	♀	1 „	7 „	
1086	Pud	♂	1 „	1 „	
900	Plazma	♀	—	7 „	
87/R	Porucznik	♂	—	5 „	
1152	Purena	♀	—	$2^1/_2$ „	
866	Poda	♀	—	—	2 days
1156	Połąga	♀	—	—	1 day

The method of my work consisted in the removal of the zygomatic arch and of the mandible and, at a later stage, of a part of the orbital margin. Preparations of especially fine nervous branches were undertaken by means of preparatory needles warranting thus more accurate results. One of the heads of an adult European bison was fixed in a 5% aqueous solution of formalin and then congealed with the aim of accomplishing transsections of the contents of the orbit. These sections enabled observations of the topographical relations in the orbit of the European bison.

III. OWN INVESTIGATIONS

1. The orbit *(orbita)*

The orbit (Fig. 1) is limited by the *os zygomaticum, os frontale, os lacrimale* and the *ala orbitalis ossis sphenoidei* (Fig. 1 E, B, A, C). *Aditus orbitae* (K o l d a, 1936) limits the *margo orbitalis*. The orbital margin of the European bison is formed by the *os frontalis, lacrimalis* and *zygomaticum*. It protrudes characteristically beyond the lateral edge of the cranium and is especially apparent in the European bison male (K r y s i a k, 1951). The zygomatic bone (Fig. 1 E) which forms the inferior part of the orbital margin has on the *proc. temporalis* a significant lateral prominence, which contributes to the elongation of this part of the orbital margin. Also the *proc. frontalis* of the zygomatic bone with *proc. zygomaticus ossis frontalis* are very broad. Such a telescopical shape (K r y s i a k, 1960) of the orbital margins extends the orbit considerably in a lateral direction, especially in the male of the European bison.

On the orbital margin formed by the lacrimal bone (Fig. 1 A) a conspicuous *sulcus vascularis* is seen in the European bison, similarly as in cattle (Fig. 1a). Two strongly developed *sulci lacrimales* (Fig. 1b) appear below. The *fossa sacci lacrimalis* (Fig. 1 j) is situated more posteriorly than the sulci on the orbital surface of the *os lacrimale*; it is rather spacious and leads to the lacrimal canal. The *fossa sacci lacrimalis* shows a tendency to divide, which happens frequently in the European bison — we can then mention two *for. lacrimalia*. More posteriorly and centrally, on the orbital surface of the lacrimal bone, a strongly developed (especially in adult specimens) *sulcus muscularis* leads to the profound *fossa muscularis* (Fig. 1 c). It is situated deeply in the orbit, at a considerable distance from the orbital margin.

The orbital part of the frontal bone (Fig. 1 B) contributes also to the limitation of the medial wall of the orbit. At the base of the zygomatic process of the frontal bone lies the deep and strongly marked *fossa glandulae lacrimalia*. A weakly marked *foveola trochlearis* is situated more anteriorly. On the medial wall of the orbit the rather spacious *for. supraorbitale ventrale* (Fig. 1g) is situated, placed more anteriorly (about 3 cm) than in cattle, in relation to the *crista orbitalis aboralis*. Below this aperture and more to the front is the *for. ethmoideum* (Fig. 1 d), limited on three sides by the frontal bone, and on its narrow inferior part by the orbital wing of the sphenoid bone. The position of this aperture in the European bison differs from that found in cattle, where it is only limited by the frontal bone. Behind the *for. ethmoideum* and more to the back appears a small longitudinal depression, the *faveola muscularis*. It lies on the border of the *os frontalis* and of the *ala orbitalis ossis sphenoidei*, often on the frontal bone, near the spheno-frontal suture. It forms a place of insertion for the *m. obliquus bulbi dorsalis*.

On the border of the orbit and of the *fossa temporalis* lies the *crista orbitalis aboralis*, beginning on the *margo temporalis* of the zygomatic process of the frontal bone, running more inferiorly and prolonging itself into the *crista pterygoidea* (Fig. 1h). The *crista orbitalis aboralis* is weakly marked in its upper part in the European bison and becomes more distinct in its lower part. The *crista pterygoidea* of the European bison is lower than that of the cow, weakly developed and protruding slightly towards the front. Below the ethmoidal foramen and backwards lies on the orbital wing of the sphenoid bone a rather large *for. opticum* (Fig. 1e). It is subject to a strong narrowing in its inferior part, assuming the shape of a fissure, and it is more spherical in its superior part. On the posterior margin of the optic foramen a small process appears.

The orbital wing of the sphenoid bone forms, to the front of the optic foramen, a rather considerable eminence, on which the *crista orbitalis ventralis* appears (Fig. 1 i). It is weakly developed in the European bison and can be only found in the frontal part of the orbital wing of the sphenoid bone.

The *ala orbitalis ossis sphenoidei* adjoins frontally to the *lamina sagitalis* of the palatine bone, which in the European bison penetrates, higher than in the cranium of the cow, between the frontal bone and the lacrimal bone. It reaches the *fossa muscularis* on the lacrimal bone in nearly all of the investigated European bisons.

The orbit as a whole is considerably elongated laterally, which is especially manifest in adult individuals. It is protected in an important degree by bone material and can therefore be considered as belonging to the type of an unclosed orbit (P o p l e w s k i, 1949). The axes of both orbits are rather visibly directed towards the lateral side and form an angle, obtuse anteriorly, of obout 125°.

2. The periorbita

It has the shape of a funnel and lines the orbit. Its apex begins on the periphery of the optic foramen and of the orbito-rotundum foramen and its base is directed towards the orbital margin and grows together with it. It limits the orbit from the lateral side, which is here deprived of an osseous cover. The periorbita adheres on its medial wall to the bones limiting the orbit and penetrates into all apertures lying on this wall. From the lateral side the periorbita borders with the *m. orbitalis* coming into a close contact with it and is punctured in numerous places by the vessels and nerves which enter the orbit or depart from it. The behaviour of the periorbita of the European bison does not depart on the whole from that of domestic cattle.

3. The muscle of Müller *(m. orbitalis)*

The muscle of M ü l l e r (Fig. 2A, B) lies on the periorbita on the side of the *fossa temporalis. Corpus adiposum extraorbitale* disposes itself on the exterior of this muscle. The *m. orbitalis* of the European bison is composed of two laminae.

The *lamina superficialis* (Fig. 2A) is entirely provided with tendons. It begins with a very narrow tendon on the apex of the *crista pterygoidea,* its fibres directing themselves towards the orbital margin, broadening out in the shape of a fan and partly covering the *lamina profunda musculi orbi-*

talis. Near the orbital margin (Fig. 2) the fibres of the *lamina superficialis* are subject to a strong junction with the *lamina profunda*, while near the *crista pterygoidea* two independent laminae appear.

Lamina profunda (Fig. 2B) is much more strongly developed. It surrounds the orbit from the side of the *fossa temporalis* and inserts its anterior part between the periorbita and the *bulla lacrimalis*. The fibres of the *lamina profunda* in the neighbourhood of the periorbita come into a rather close contact with it. Some of them commence on the *crista orbitalis aboralis* on the *sutura frontopalatina*, attaining the height of the *fossa muscularis*. The muscular fibres of this lamina gradually disappear near the orbital margin and only the tendinous part is maintained, obtaining an insertion on the orbital margin. It is in this place that a strong junction of both laminae of the *m. orbitalis* appears.

Between the two laminae of the muscle of Müller runs the *ramus lateralis nervi lacrimalis* (Fig. 2c) in the European bison. In one isolated case (Poda) this branch ran entirely under the *m. orbitalis*, perforating it only in its upper part, together with the *ramus medialis nervi lacrimalis*.

4. The orbital fasciae

Three fasciae appear in the orbit of the European bison.

The *fascia orbitalis superficialis* covers the entire content of the orbit, adheres to the periorbita and commences on the peripheries of the optic foramen and the *for. orbitorotundum*. Having attained the height of the eyeball it further runs in the eyelids. The superficial fascia of the European bison is a relatively strong and thick membrane. With it coalesces the trochlea, upon which the *m. obliquus bulbi dorsalis* is entwined.

On the level of the eyeball the superficial fascia is perforated by the *m. obliquus bulbi ventralis* (Fig. 4). Around this puncture the superficial fascia thicken, forming a ring, upon which the *m. obliquus bulbi ventralis* is wound, changing the direction of its course.

Fascia orbitalis profunda is thin and delicate. It commences around the optic foramen and divides into two laminae. The *lamina superficialis* of the deep orbital fascia lies on the straight muscles of the eyeball, adhering to them externally, and is relatively thin in the European bison. On the course of the *m. obliquus bulbi dorsalis* the *lamina superficialis* of the deep fasciae grows together around this muscle with the superficial fascia which covers it externally. In this manner a fascial canal is formed for the *m. obliquus bulbi dorsalis*. The *lamina superficialis* grows together with the internal surface of the trochlea, running further in the eyelids. The *lamina profunda* of the deep fascia runs in a way similar to that of the superficial one, but surrounds internally the straight muscles of the eyeball.

The *fascia bulbi Tenoni* lies the most profoundly in the orbit. It is well developed. It begins around the optic foramen and covers externally the *m. retractor bulbi.* It then passes onto the eyeball, ending in the vicinity of the margin of the cornea. The space contained between the lamina profunda of the *fasciae prof.* of the orbit and the *fascia bulbi* is filled by the *corpus adiposum intraorbitale* (Figs. 13—15B), strongly developed in the European bison.

5. **Extrinsic muscles of the eye** *(mm. bulbi)*

It is known that the extrinsic muscles of the eye are situated in the orbit. The European bison possesses, like other mammals, four straight muscles, two *mm. obliqui*, a *m. retractor bulbi* and the *m. levator palpebrae frontalis.*

M. rectus bulbi dorsalis (frontalis) (Figs. 10—15 d) lies in the upper part of the orbit. It begins on the dorsal part of the optic foramen above the insertion of *m. retractor bulbi* (Fig. 3e') and runs in the direction of the eyeball. In the vicinity of the trochlea it receives a small tendo from the *m. obliquus bulbi dorsalis* (Fig. 5a'), which passes into the muscular fibres of the anterior margin of *musculus rectus bulbi dorsalis.* In its further course, the *m. rectus bulbi dorsalis* obtains an insertion on the sclera (Fig. 3 e) at a distance of about 4 mm. from the margin of the cornea. On the internal surface of *m. rectus bulbi dorsalis* run the trochlear nerve and the frontal nerve, while on the internal one — the *ramus dorsalis* of the oculomotor nerve.

M. rectus bulbi ventralis (maxillaris) (Figs. 10—15 b) commences in the E. bison as a broad tendom around the inferior fissure-like part of the optic foramen (Fig. 3b'). It adjoins the insertions of *m. rectus bulbi temporalis et nasalis.* In its initial course it coalesces with the tendon of the *m. rectus bulbi temporalis*, then this muscle directs itself towards the eyeball, passes under the *m. obliquus bulbi ventralis* and ends with a tendo on the sclera (Fig. 3 b) at a distance of about 4—5 mm. from the margin of the cornea. Along the interior surface of this muscle runs the *ramus ventralis* of the oculomotor nerve, which passes later onto the external surface.

M. rectus bulbi nasalis s. medialis (Figs. 10—15 a) runs in the medial part of the orbit. In the European bison it begins with a very broad tendo round the spherical part of the optic foramen (Fig. 3a') on its dorsal and anterior frame. It runs in the direction of the eyeball, surrounding the *n. opticus* (Fig. 10—11 a) in its initial segment, similarly as in the sheep (N u s s b a u m, 1902). This muscle ends on the paracentral part of the eyeball (Fig. 3a) at a considerable distance from the margin of the cornea (6—7 mm).

M.rectus bulbi temporalis s. lateralis (Figs. 10—15c) lies on the lateral side of the orbit. It begins, in the European bison, as a very narrow and long tendon, a little further than the optic foramen (Fig. 3 c') on its inferior, fissure-like part, between the *m. rectus bulbi ventralis* and the *m. retractor bulbi. M. rectus bulbi temporalis* is subject to coalescence in its initial course with the *m. rectus bulbi ventralis* and with the *m. retractor bulbi.* The muscle under discussion runs further on the eyeball and covers the *m. obliquus bulbi ventralis.* In this place it receives from it a small tendon (Fig. 6 a''), which passes into the muscular fibres of the anterior margin of the *m. rectus bulbi temporalis.* This muscle has an insertion on the sclera, very near (about 2 mm.) to the margin of the cornea. On the medial margin of the *m. rectus bulbi temporalis* runs the principal branch of the obducent nerve, similarly as in the cow (F r a n k, l.c.).

M. obliquus bulbi ventralis (maxillaris) (Figs. 14—15f) runs in the nasal part of the orbit and is relatively strongly developed in comparison with the remaining muscles of the eyeball. It begins in the *fossa muscularis* of the lacrimal bone, proceeds further in the direction of the eyeball in the *sulcus muscularis ossis lacrimalis,* between the periorbita and the superficial fascia (Figs. 14, 15f). It forms on the level of the eyeball a strong inflection towards the back (Fig. 4), perforates the superficial fascia, then the deep fascia and runs on the ventral surface of the eyeball. It then passes onto the exterior of the *m. rectus bulbi ventralis,* and before penetrating under the *m. rectus bulbi temporalis* divides, in the European bison, into three terminal branches.

Ramus lateralis (Figs. 4, 6 a') penetrates under the *m. rectus bulbi temporalis* and, by means of a short tendo, obtains an insertion on the sclera, immediately behind the line of insertion of the *m. rectus bulbi temporalis,* at a distance of about 2 mm from the margin of the cornea.

Ramus medius (Figs. 4, 6 a'') is very slender and forms, a long and narrow tendo (about 2 mm. broad), which twists backwards, passing into the muscular fibres of the margin of *m. rectus bulbi temporalis.*

Ramus medialis (Figs. 4, 6 a'''), usually the broadest and strongly expressed, proceeds in the vicinity of the posterior pole of the eyeball. Its most medial fibres lie even immediately behind the eyeball (Fig. 6). It inserts itself gradually on the *fascia bulbi (Tenoni),* which covers the *m. retractor bulbi ventralis* situated here.

The locus of the passage of *m. obliquus bulbi ventralis* through the superficial fascia, showing here a certain thickening, play a role similar to that of the trochlea in relation to this same muscle. It must be noted that the *m. obliquus bulbi ventralis* of the European bison runs in the orbit nearly parallelly to the straight muscles of the eyeball (Figs. 14, 15 f) up to the moment of puncturing of the superficial fascia. This segment about

4 cm. long, may be submitted to fluctuations as to its length in an adult European bison.

M. obliquus bulbi dorsalis (frontalis) of the European bison (Figs. 11—15e) runs in the superior part of the orbit in a special fascial canal. It is more weakly developed in relation to the remaining muscles. Its beginning is situated in a special *fossula muscularis* lying on the frontal bone near or on the *sutura frontosphenoidalis* itself. The breadth of the insertion fluctuates in the limits of about 7 mm. The belly of the muscle, narrow and slender, is directed towards the eyeball and reaches the trochlea, twining around it and changing the direction of its course. It enters under the *m. rectus bulbi dorsalis* and, after emerging, obtains an insertion on the lateral part of the eyeball. Sometimes the *m. obliquus bulbi dorsalis* is terminated on the sclera, under the *m. rectus bulbi dorsalis*. The eyeball insertion of this muscle (Figs. 3g, 6c) lies near the insertion of *Ramus lateralis mi. obliquui bulbi ventralis*, but is relatively more distant from the margin of the cornea, so that it is placed in the neighbourhood of the insertion of *m. retractor bulbi*, and its tendo often divides the fibres of the muscle mentioned lastly.

Having passed by the trochlea the *m. obliquus bulbi dorsalis* of the European bison sends out a small tendo (Fig. 5 a') (about 1.5 mm. broad) which penetrates under the *m. levator palpebrae frontalis* and joins the *m. rectus bulbi dorsalis*. This junction did not take place in all of the cases (there was none in Połąga).

M. retractor bulbi (Figs. 10—15 g) proceeds the most medially in relation to the straight muscles of the eyeball. In the European bison it is a thick and well-developed muscle. It begins on the posterior frame of the fissure-like part of the optic foramen (Fig. 3d), having an upward insertion between *m. rectus bulbi dorsalis* upwards and *m. rectus bulbi temporalis* downwards. The insertion of this muscle occupies a large surface and protrudes even on the process situated on the posterior margin of the optic foramen. It proceeds towards the eyeball, coalescing near the bone insertion, on a small section only, with *m. rectus bulbi temporalis*. *M. retractor bulbi* in its initial segment covers the optic nerve only laterally (Figs. 10—12 g) and only at a small distance from the posterior pole of the eyeball it starts covering the optic nerve from the dorsal and ventral side (Figs. 13—15 g).

On the level of the eyeball it surrounds it from all sides, covering its entire posterior hemisphere and ending on the sclera near the equator. A part of its fibres, situated more internally, obtains an insertion on the posterior part of the eyeball (Fig. 7 b') on the arched line above the optic nerve. *M. retractor bulbi* does not show in the European bison a tendency of dividing into four parts as in the cow and the sheep (C o r d s, l.c.).

M. levator palpebrae frontalis (Figs. 10—15 h) of the European bison is a well-expressed muscle running on the dorsal surface of *m. rectus bulbi dorsalis*. It begins dorsally in relation to the insertions of *m. rectus bulbi dorsalis* and *nasalis* (Fig. 3 f) a little further from the margin of the optic foramen. It runs in the direction of the eyeball, passing under the lacrimal gland, where it spreads out in a fan-like manner and extends itself on the upper eyelid.

6. Innervation of the extrinsic muscles of the eye

The extrinsic muscles of the eye in the European bison, as in other ruminants, receive nervous fibres in the first place from three cranial nerves: the oculomotor, the trochlear and the abducent nerve.

N. oculomotorius passes into the orbit through the *foramen orbitorotundum*. When still in the area of this aperture it divides into the *ramus dorsalis* and the *r. ventralis*.

The *ramus dorsalis,* when still on the terrain of the orbit, is directed dorsally and runs on the internal surface of the *m. rectus bulbi dorsalis* in the shape of two ramules. After a relatively short course these ramules penetrate into the *m. rectus bulbi dorsalis,* ramifying in it, and two or three small ramules pass through this muscle into the *m. levator palpebrae frontalis.*

The *ramus ventralis* is much longer and thicker and runs between the *m. rectus bulbi dorsalis* and the *m. retractor bulbi,* near their insertions on the bone. It approaches the optic nerve and runs along its inferior margin. It is then directed slightly to the front, comes near to the *m. rectus bulbi ventralis* and runs further on its internal surface. Here it sends out a twig to the*m. rectus bulbi nasalis.* The twig proceeds towards the front, paracentrally, winds around the anterior margin of the optic nerve and penetrates into the internal surface of the *m. rectus bulbi nasalis.* The very short twig of the ventral branch of the oculomotor nerve is the next ramification; it runs to the *m. rectus bulbi ventralis,* penetrating into its interior surface in the shape of two secondary twigs. In its further course the ventral branch sends out twigs to the *ganglion ciliare* and, having accomplished this, the ventral branch of the oculomotor nerve becomes relatively slender. It then runs in the direction of the posterior margin of the *m. rectus bulbi ventralis,* entwines it and passes onto the external surface of the afore-mentioned muscle. Following this surface it reaches the *m. obliquus bulbi ventralis* and penetrates into its medial margin. In the place where the ventral branch winds on the posterior margin of the *m. rectus bulbi ventralis* two or three twigs of the zygomatic nerve approach it and attain the *m. obliquus bulbi ventralis* in a common stem.

The *n. trochlearis* of the European bison runs paracentrally in the *for. orbitorotundum*. In the orbit, it passes on the external surface of the *m. rectus bulbi dorsalis* and of the *m. levator palpebrae frontalis*. Having reached the *m. obliquus bulbi dorsalis* it divides into several twigs which penetrate onto the medial surface and the posterior margin of this muscle. In one of the European bison preparations (Porucznik) a twig of the frontal nerve ran with the trochlear nerve, forming a common stem. In this case it separated before reaching the *m. obliquus bulbi dorsalis* and ramified on its external surface.

The *n. abducens* of the European bison also passes into the orbit through the *for. orbitorotundum* and runs between the *m. rectus bulbi temporalis* and the *m. retractor bulbi*. After entering the orbit it divides into two branches, the cardinal and the accessory one, similarly as in the cow (F r a n k, l.c.). The cardinal branch runs on the medial surface of the *m. rectus bulbi temporalis* in the shape of two stems, which divide into yet smaller twigs and penetrate into the *m. rectus bulbi temporalis*. The accessory branch is more slender than the previous one and after a very short course on the external surface of the *m. retractor bulbi*, penetrates inside and is divided into three twigs. Two of them are thinner, and one thicker one is again divided into two secondary ones. Finally, four twigs are formed, two of which innervate a segment of the nerve situated to the front of the optic nerve, while the other two innervate the rear segment. In the two European bisons I prepared (Porucznik, Poda) I observed a separate course of these three twigs of the accessory branch from the moment of division of the abducent nerve.

The extrinsic muscles of the eye of the European bison receive small twigs from the trigeminal nerve, which reach them by means of the zygomatic, frontal and nasociliary nerve.

N. zygomaticus of the European bison (Fig. 8 A), after its departure from the maxillary nerve, penetrates into the orbit having transperced the *m. orbitalis* and the *periorbita*. On entering the orbit it divides into three branches: the *cranialis*, *medius* and *caudalis* branch. *Ramus cranialis* (Fig. 8 A') is usually the thickest and runs in the inferior part of the orbit in the direction of the lower lid, ramifying in the conjunctiva. *Ramus medius* (Fig. 8 A''), thinner than the previous one, perforates the superficial fascia immediately after leaving the stem, and penetrates deeper into the orbit. It runs in a sulcus between the *m. rectus bulbi ventralis* and the *temporalis*, sending out a twig (Fig. 8b) which passes on the external surface of the *m. rectus bulbi ventralis*, penetrating into it on this same surface. It sends out again, a little further, one or two twigs (Fig. 8c), which also penetrate into this muscle near its posterior margin. *Ramus medius* also sends out a twig in the direction of the ciliary ganglion (Fig.

8 d), itself joining the *ramus ventralis* of the oculomotor nerve (Fig. 8 e, e') thus conducting its fibres up to the *m. obliquus bulbi ventralis. Ramus caudalis* (Fig. 8 A'''), the thinnest of the three, runs on the external surface of the *m. rectus bulbi temporalis,* sending out into it several small twigs (Fig. 8 a) and directing itself towards the conjunctive of the lower eyelid. These three branches of the zygomatic nerve ran in a single stem in three European bisons (Pluszcz, Tatra, Plato) and then this stem proceeded externally on the *m. orbitalis.* It sent out gradually at first the *ramus caudalis,* which immediately punctured the *m. orbitalis* and the *periorbita,* then, on a higher level the *ramus medius* departed, while the *ramus cranialis* entered the orbit on the highest level. The further course of these three branches of the zygomatic nerve on the terrain of the orbit corresponds to the relations described previously. These three branches of the zygomatic nerve are often connected with each other by means of the *rami communicantes.*

N. zygomaticus accessorius of the European bison (Fig. 8 C) departs from the maxillary nerve on the level of the posterior margin of the *bulla lacrimalis.* It passes upon the medial margin of the lacrimal bulla together with to the malar artery and divides into two terminal branches, of which the stronger one reaches the *m. obliquus bulbi ventralis,* penetrating into its belly near the insertion in the *fossa muscularis,* and the second one, usually weaker, attains the lacrimal caruncle. I ascertained the appearance of the this muscular branch in three specimens (Tatra, Porucznik, Pluszcz).

In all prepared European bisons appeared the nervous branch (Fig. 8 B), departing from the maxillary nerve anteriorly in relation to the zygomatic nerve. The presence of such a branch in cattle is not noted by any of the authors I have cited. This branch does not supply the extrinsic muscles of the eye.

N. frontalis of the European bison penetrates into the orbit through the *for. orbitorotundum* and runs dorsally in relation to the *m. rectus bulbi dorsalis.* Here it sends out a twig (Fig. 9 B') which, after a short course on the external surface of the *m. rectus bulbi dorsalis,* divides into two secondary twigs (Fig. 9). One of them directs itself towards the above-mentioned muscle, while the remaining one penetrates into the *m. levator palpebrae frontalis* on its external surface. The frontal nerve runs further on the external surface of the *m. obliquus bulbi dorsalis,* sending out into it small twigs (Fig. 9 B''), and continues to run in the dorsal part of the orbit. *Nervus frontalis* proceeds dorsally in the vicinity of the trochlear nerve, behaving in the manner already noted in the description of *nervus trochlearis.*

N. nasociliaris of the European bison, similarly as that of cattle (S c h a c h t s c h a b e l, l.c.; K l i m o w & A k a j e w s k i, l.c.) also supplies the extrinsic muscles of the eye. Having entered the orbit it passes between the *m. rectus bulbi dorsalis,* the *m. retractor bulbi* and the *m. rectus bulbi nasalis.* Here it sends out a small intramuscular twig (Fig. 9 A') which divides into two secondary ones; they penetrate into the *m. retractor bulbi* and the *m. rectus bulbi nasalis.* The nasociliary nerve further passes between the *m. rectus bulbi nasalis* and the *m. obliquus bulbi dorsalis* and divides into the infra-trochlear nerve and the ethmoidal nerve.

Nervus infratrochlearis of the European bison runs along the anterior margin of the *m. rectus bulbi nasalis* and is covered by the *m. obliquus bulbi dorsalis.* In some European bisons (Poda, Pud) I observed twigs departing from the infra-trochlear nerve and directed to the *m. rectus bulbi nasalis.* In these cases the naso-ciliary nerve sent out a twig to the *m. retractor bulbi* only. In one case (Porucznik) the ethmoidal nerve sent out a twig to the *m. rectus bulbi nasalis* and then there was also a lack of the *n. nasociliaris* twig directed towards the muscle mentioned above.

IV. RESULTS

The observations and investigations carried out on the anatomic structure of some of the appendages of the eye of the European bison in comparison with those of the cow (and other ruminants) demonstrate many different features.

The bone frame of the orbit in the European bison shows a series of differences in relation to the orbit of the cow. The orbital margin of the European bison protrudes considerably beyond the lateral border of the cranium (K r y s i a k, 1951), which is hardly observed in the cow. On the lacrimal bone of the European bison appears a well marked *sulcus muscularis,* which is not noticed in the cow, while the *fossa muscularis* is well expressed and situated deeper in the orbit of the European bison. On the orbital margin of the lacrimal bone of the European bison appear distincly two *sulci lacrimales,* while in the cow only one is described (M a r t i n, l.c.). The *fossa sacci lacrimalis* is often subject to division and then two *forr. lacrimalia* appear in the European bison. The *foramen supraorbitale ventrale* has been considerably shifted forward from the *crista orbitalis ventralis* in the European bison, while in the cow it lies near this crista. The *for. ethmoideum* is situated on the frontal bone, and the *ala orbitalis ossis sphenoidei* limits it only in a slight degree, while in the cow the frontal bone borders it completely. The *crista pterygoidea* is low in the European bison and does not demonstrate as strong a development as in the cow. The *crista orbitalis ventralis* is weekly delineated in the European bison and it can only be found in the anterior segment. In the orbit of the cow the lacrimal bone adjoins the sphenoidal bone, while in the European bison they are divided by the *lamina perpendicularis ossis palatini* pressing in between them.

The orbit of the European bison is more elongated in a lateral direction than that of the cow. This is caused principally by the strong development of the orbital margin. The axes of both orbits form between them a rather considerable angle of about 125^0. The value of this angle is similar to the corresponding angle in the sheep (128° — Nickel & Schummer & Seiferle, 1954) and does not resemble that of the cow (90° — N.S.S.).

The *periorbita* does not show any essential differences.

The *m. orbitalis* of the European bison is composed of two laminae. The *lamina superficialis* is entirely tendinous. In the literature cited below there is no accurate description of this muscle in cattle, while in the sheep (Harling, l.c.) and in the elk (Groyer, l.c.) both laminae are of a muscular character.

The orbital fasciae of the European bison do not differ greatly from the corresponding fasciae of the cow. The superficial fascia of the orbit is strongly developed in the European bison and thickens in the place where it is punctured by the *m. obliquus bulbi ventralis*. This thickening of the superficial fascia, in the shape of a ring, performs the role of a trochlea for the *m. obliquus bulbi ventralis*. This muscle commences in the depth of the orbit of the European bison, running for a certain length nearly parallelly to the straight muscles of the eyeball and changes the direction of its course only on the level of the eyeball. The existence of the above-mentioned ring is necessary for enabling the *m. obliquus bulbi ventralis* to perform its proper function. *M. obliquus bulbi ventralis* of the European bison, as I have already mentioned, is more strongly developed than the *m. obliquus bulbi dorsalis* and is divided into three terminal branches, of which only the *ramus lateralis*, with regard to its insertion on the sclera, is opposed in its action to that of *m. obliquus bulbi dorsalis*. The literature to which I had access, concerning the extrinsic muscles of the eye, does not mention such a division of this muscle in the cow or in other ruminants. The existence of three terminal branches of the *m. obliquus bulbi ventralis* must undoubtedly have its reflexion in the complex function of this muscle. The *ramus medius* of the *m. obliquus bulbi ventralis* becomes connected with the *m. rectus bulbi temporalis*. A similar connection exists between the *m. rectus bulbi dorsalis* and the *m. obliquus bulbi dorsalis*. The presence of those connections in the European bison, which have not hitherto been described in the cow, can be a proof of the affinity of the activities of these muscles in the European bison. The *ramus medialis m. obliquus bulbi ventralis* of the European bison provokes, with the cooperation of the *m. obliquus bulbi dorsalis,* the forward movement of the eyeball in the orbit and turns the optic axis in a dorso-lateral direction.

The straight muscles of the eye in the European bison have an insertion on the sclera at a different distance from the margin of the cornea. The insertion of the *m. rectus bulbi nasalis* is the most distant (6—7 mm.) while that of the *m. rectus bulbi temporalis* is the nearest (1.5—2 mm.). Similar insertions of the muscles mentioned above render possible the lateral deviation of the optic axis in relation to the orbital axis.

Table 2.

Innervation of the extrinsic muscles of the eye of the European bison

Name of muscle	by	
	branches of nerves III, IV, VI	branches of nerve V
M. rectus bulbi dorsalis	the dorsal branch of the oculomotor nerve	the branch of the frontal nerve
M. obliquus bulbi ventralis	the ventral branch of the oculomotor nerve	the middle branch of the zygomatic nerve
M. rectus bulbi nasalis	the ventral branch of the oculomotor nerve	the branch of the naso-ciliary nerve
M. rectus bulbi temporalis	the cardinal branch of the abducent nerve	the posterior branch of the zygomatic nerve
M. rectus bulbi ventralis	the ventral branch of the oculomotor nerve	the middle branch of the zygomatic nerve
M. obliquus bulbi dorsalis	the trochlear nerve	the branch of the frontal nerve
M. retractor bulbi	the accessory branch of the abducent nerve	the branch of the naso-ciliary nerve
M. levator palpebrae frontalis	the dorsal branch of the oculomotor nerve	the branch of the frontal nerve

The innervation of the extrinsic of the eye of the European bison approaches, in a general outline, the conditions observed in the cow. The innervation of the *m. retractor bulbi* in the European bison is in accordance with the observations of Frank (1949) on the innervation of this same muscle in the cow. I could not confirm, however, the existence of twigs of the oculomotor nerve destined for the *m. retractor bulbi.*

The trigeminal nerve in the European bison conducts its twigs to the extrinsic muscles of the eye through the zygomatic nerve, the frontal nerve and the nasociliary nerve. The fibres that have been mentioned are probably of a sensory character, similar to that described in the cow

(Ellenberger & Baum, l.c.) and the sheep (Nussbaum, 1902). Sensory innervation of the extrinsic muscles of the eye of the cow and the sheep in the works I have cited above was treated in a general and fragmentary manner. As a result of investigations on the innervation of these muscles in the European bison I have ascertained the existence of twigs of the trigeminal nerve, destined for all extrinsic muscles of the eye. This has been presented in the description and in table 2.

V. SUMMARY

The author carried out investigations on cadavers of European bisons of different age, either fresh or fixed in an aqueous formalin solution and, additionally, on 35 skulls of European bisons.

A series of traits, characteristic for this species, were determined.

The orbit presents a considerable lateral elongation, especially in adult individuals. The cause of this state of things must be sought in the telescopic formation of orbital margins, which protrude characteristically beyond the lateral border of the skull. The axes of both orbits are decidedly directed laterally, forming an angle of about 125°. (In cattle the corresponding angle amounts to 94° and to 128° in sheep). The muscular fossa lying on the lacrimal bone is situated deeply in the orbit, at a considerable distance from the orbital margin. The orbital muscle is composed of two lamellae: the superficial one is completely tendinous and the profound one is much more strongly developed, with muscular fibres running transversally in relation to the orbital axis.

The superficial fascia of the orbit shows a thickening in the shape of a ring, in the place where it is transperced by *m. obliquus bulbi ventralis*. This ring performs a role similar to that of a trochlea, changing the direction of the course of fibres of the muscle mentioned above.

The straight muscles of the eye obtain an insertion on the sclera at different distances from the margin of the cornea. *M. rectus bulbi nasalis* of the European bison surrounds the optic nerve in its initial segment, similarly as in the sheep. *M. obliquus bulbi ventralis* divides near the eyeball into three branches: the lateral branch, ending on the sclera, the central branch, joining *m. rectus bulbi lateralis*, and the medial one, obtaining an insertion on the fascia of the eyeball (Tenon).

The author also investigated morphologically the relations of nerve twigs supplying the extrinsic muscles of the eye of the European bison. These muscles receive nerve fibres from cranial muscles III, IV and VI, and from the trigeminal nerve, by means of the *zygomaticus*, *frontalis* and *nasociliaris* nerves.

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STRESZCZENIE

Autor przeprowadził badania na dziesięciu świeżych i utrwalonych w roztworze wodnym formaliny zwłokach żubrów w różnym wieku oraz dodatkowo na 35 czaszkach żubrów, ze zbiorów Ośrodka Badań nad Anatomią Żubra przy Zakładzie Anatomii Zwierząt SGGW w Warszawie.

Przeprowadzone badania nad okolicą oczodołową żubra pozwoliły ustalić szereg cech charakterystycznych dla tego gatunku.

Oczodół wykazuje znaczne wydłużenie w kierunku bocznym, co szczególnie manifestuje się u osobników dorosłych. Przyczyny tego wydłużenia należy szukać w teleskopowatym ukształtowaniu pierścieni oczodołowych, wystających charakterystycznie poza boczną krawędź czaszki. Osie obu oczodołów zwrócone są zdecydowanie w kierunku bocznym i tworzą ze sobą kąt około 125°. (U bydła odpowiedni kąt wynosi 94°, u owcy 128°.). Dół mięśniowy leżący na kości łzowej znajduje się głęboko w oczodole, w znacznej odległości od krawędzi oczodołowej. Mięsień oczodołowy składa się z dwóch blaszek: powierzchownej, całkowicie uścięgnionej i głębokiej, znacznie silniej rozwiniętej, której włókna mięśniowe przebiegają poprzecznie w stosunku do osi oczodołu.

Powięź powierzchowna oczodołu wykazuje zgrubienie w postaci pierścienia, w miejscu przebicia jej przez m. skośny gałki ocznej brzuszny. Pierścień ten spełnia

rolę podobną do bloczka, zmieniając kierunek przebiegu włókien wyżej wymienionego mięśnia.

Mięśnie proste gałki ocznej uzyskują przyczep na twardówce, w różnej odległości od krawędzi rogówki. M. prosty gałki ocznej przyśrodkowy u żubra otacza nerw wzrokowy w jego odcinku początkowym, podobnie jak to ma miejsce u owcy. M. skośny gałki ocznej brzuszny w pobliżu gałki ocznej dzieli się na trzy gałęzie: boczną, kończącą się na twardówce, środkową, łączącą się z mięśniem prostym gałki ocznej bocznym i przyśrodkową, uzyskującą przyczep na powięzi gałki ocznej (Tenona).

Autor przebadał również morfologiczne stosunki gałązek nerwowych zaopatrujących mięśnie zewnętrzne gałki ocznej żubra. Wspomniane mięśnie otrzymują włókna nerwowe nerwów czaszkowych III, IV i VI, oraz z nerwu trójdzielnego poprzez nerwy: jarzmowy, czołowy i nosoworzęskowy.

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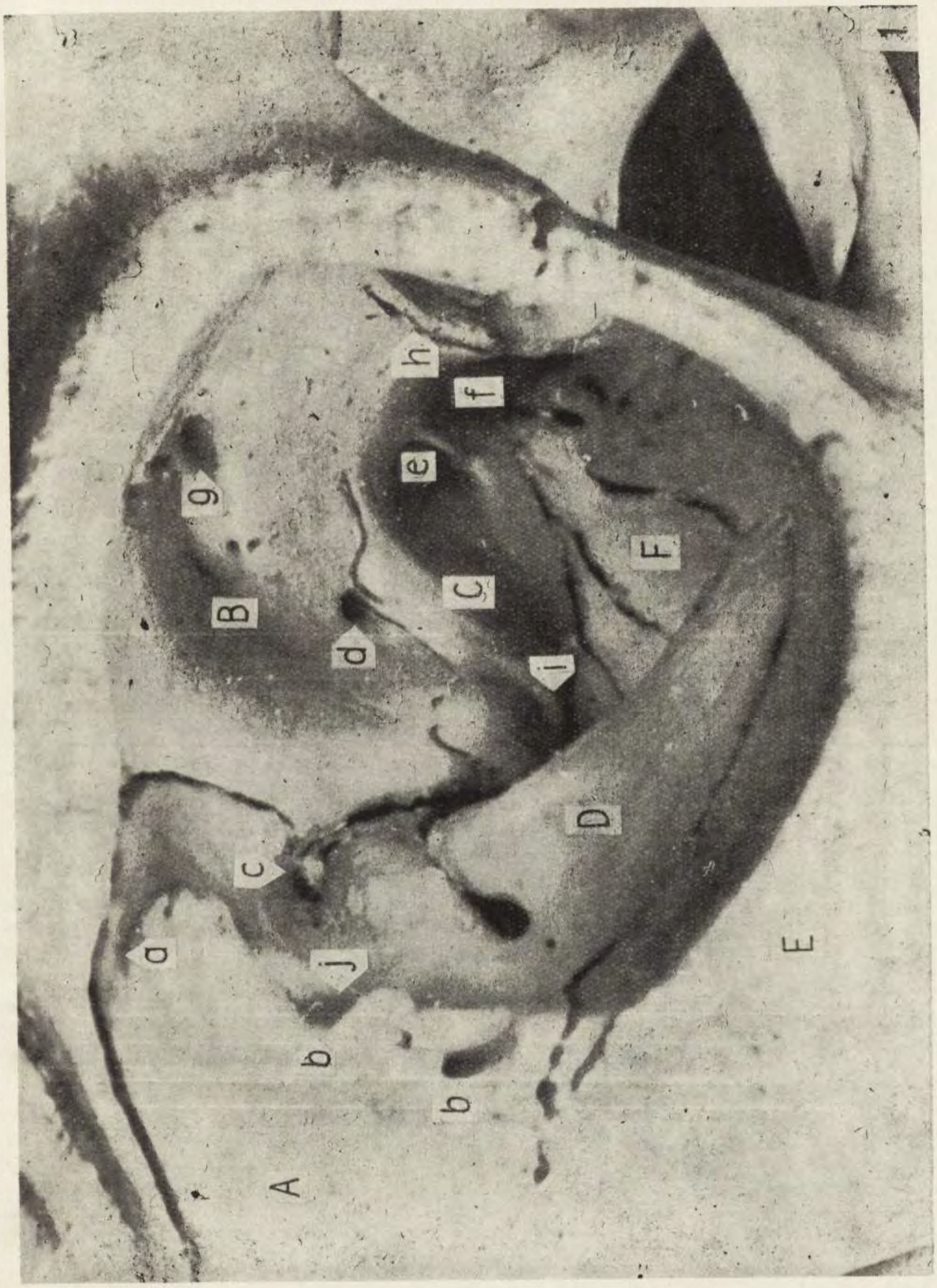
FIGURES

Plate XLVII.

Fig. 1. Orbit of the European bison (seen through the orbital margin).

A — lacrimal bone, B — frontal bone, C — *ala orbitalis ossis sphenoidei*, D — lacrimal bulla, E — zygomatic bone, F — perpendicular lamina of the palatine bone, a — sulcus vascularis, b — *sulci lacrimales*, c — *fossa muscularis*, d — *foramen ethmoideum*, e — optic foramen, f — *foramen orbitorotundum*, g — *foramen supraorbitale ventrale*, h — *crista pterygoidea*, j — *fossa sacci lacrimalis*.



M. Węgrzyn auctor phot.

Plate XLVIII.

Fig. 2. Diagram of the orbital muscle of the European bison.
A — superficial lamina, B — profound lamina, a — maxillary nerve, b — zygomatic nerve, c — lateral branch of the lacrimal nerve, I — lacrimal bulla, II — *crista pterygoidea*, III — orbital margin.

Fig. 3. Diagram of insertions of extrinsic muscles of the eye of the European bison.
a, a' — *m. rectus bulbi medialis;* b, b' — *ventralis;* c, c' — *temporalis;* e, e' — *dorsalis;* d — *retractor bulbi;* f — *m. levator palpebrae frontalis;* g, g' — *m. obliquus bulbi dorsalis;* i — *ventralis;* I — optic foramen; II — *foramen ethmoideum.*

Fig. 4. Diagram of the course and division of the *m. obliquus bulbi ventralis* of the European bison.
a' — lateral branch; a" — *ramus medius;* a'" — medial branch of the *m. obliquus bulbi ventralis;* b — superficial fascia of the orbit.

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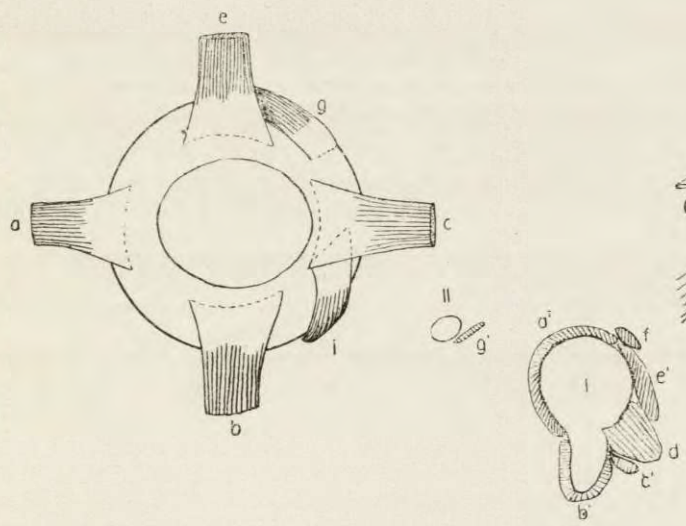

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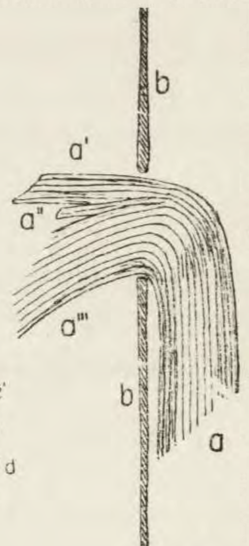

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Plate XLIX.

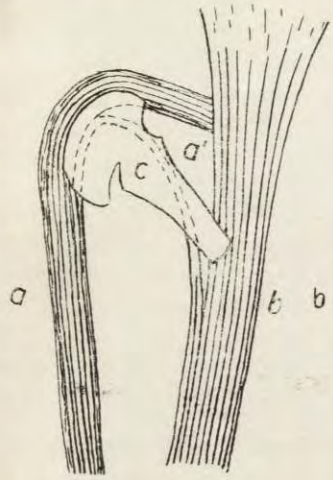
Fig. 5. Diagram of the anastomose of the *m. obliquus bulbi dorsalis* and the *m. rectus bulbi dorsalis* of the eyeball in the European bison.
a — *m. obliquus bulbi dorsalis;* b — *m. rectus bulbi dorsalis;* a' — tendon branch uniting both muscles; c — trochlea.

Fig. 6. Diagram of insertions of extrinsic muscles of the eye on the temporal surface of the eyeball of the European bison.
a — *m. obliquus bulbi ventralis;* a', a'', a''' — its lateral. central and medial branches; b — *m. rectus bulbi temporalis;* c — *m. obliquus bulbi dorsalis;* d — *m. retractor bulbi.*

Fig. 7. Diagram of the eyeball insertion of the *m. retractor bulbi* of the European bison.
a — sclera; b, b' — *m. retractor bulbi;* c — optic nerve.

Fig. 8. Diagram of the division of the zygomatic nerve of the European bison.
A — zygomatic nerve; A', A'', A''' — its anterior, central and posterior branch; B — central zygomatic nerve; C — accessory zygomatic nerve; a — twig leading to the *m. rectus bulbi temporalis;* b, c — twigs to the *m. rectus bulbi ventralis;* d — twig to the ciliary ganglion; e, e' — twigs to the oculomotor nerve; I — maxillary nerve; II — ventral branch of the oculomotor nerve.

Fig. 9. Diagram of the course of intramuscular twigs of the nasociliary nerve and the frontal nerve.
A — nasociliary nerve; B — frontal nerve; a — *m. retractor bulbi;* b — *m. rectus bulbi medialis;* c — *m. rectus bulbi dorsalis;* d — *m. levator palpebrae frontalis;* e — *m. obliquus bulbi dorsalis;* I — optic nerve; II — *foramen ethmoideum.*



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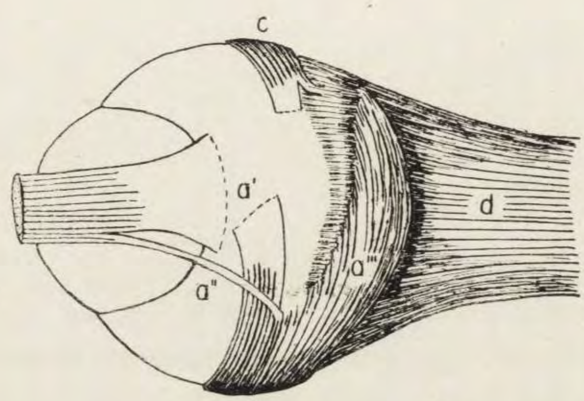

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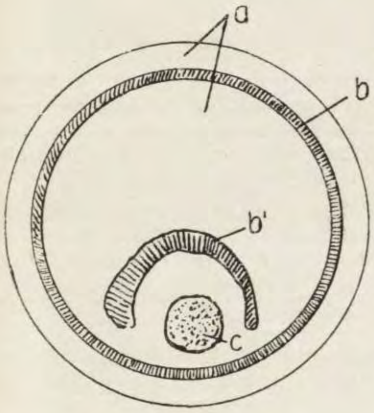

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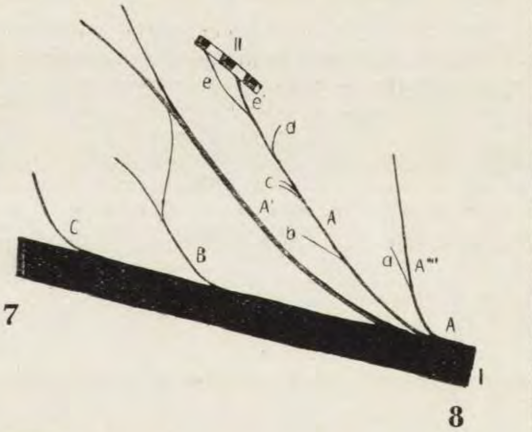

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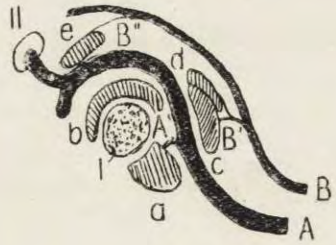

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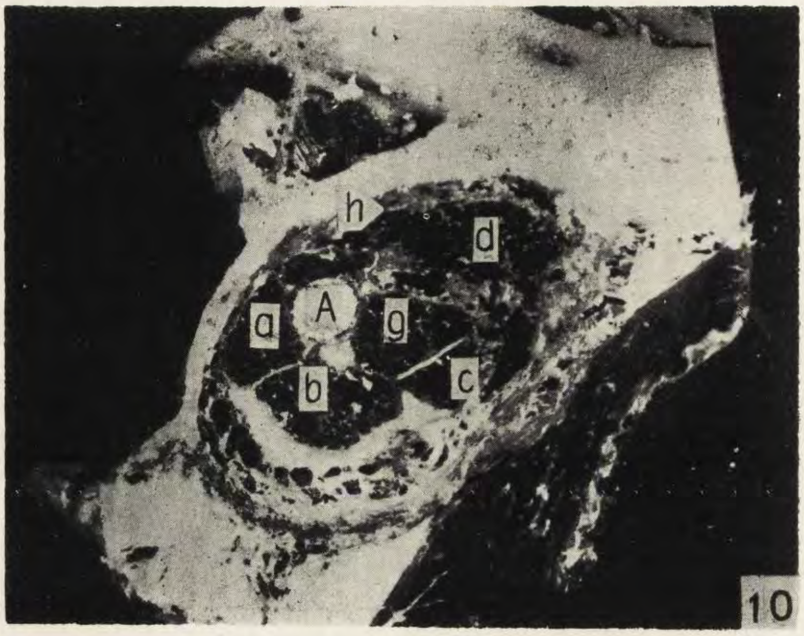
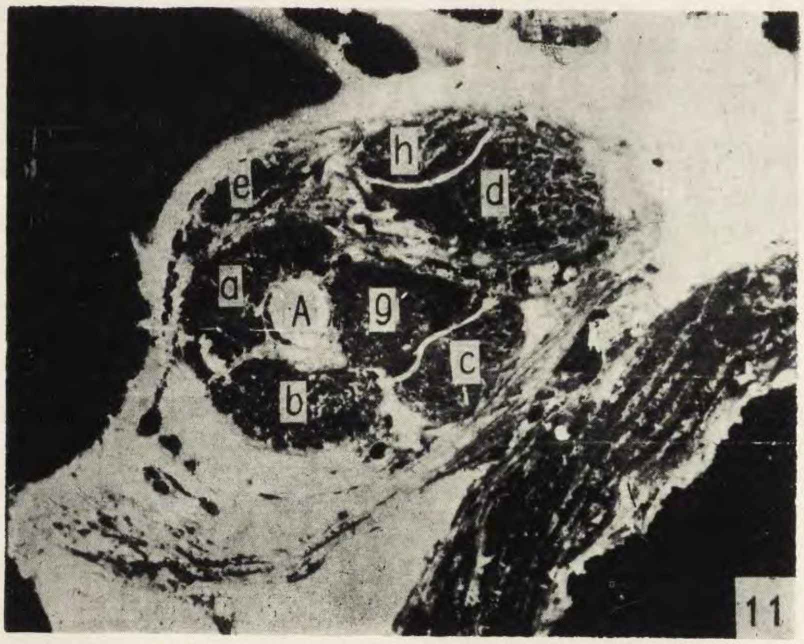
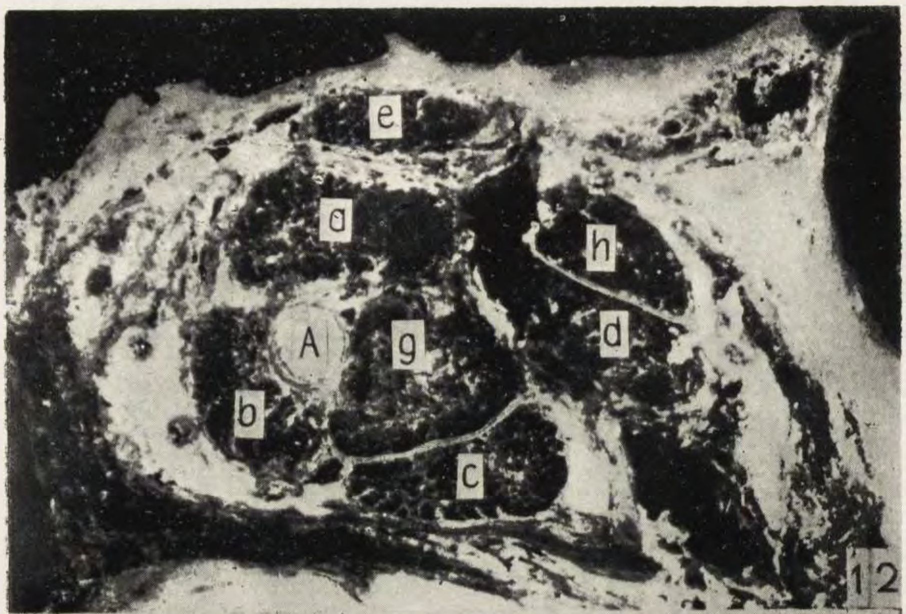
Plates L—LII.

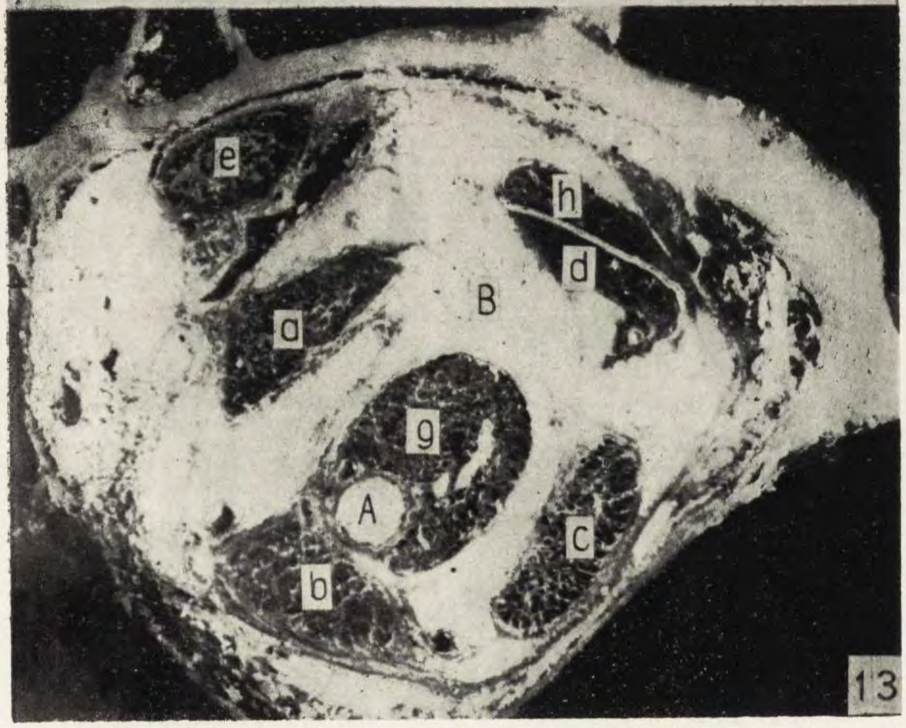
Figs. 10—15. Transsections of the contents of the orbit of the European bison. a — *m. rectus bulbi medialis;* b — *ventralis;* c — *temporalis;* d — *dorsalis;* e — *m. obliquus bulbi dorsalis;* f — *ventralis;* g — *m. retractor bulbi;* h — *m. levator palpebrae frontalis;* A — optic nerve; B — intraorbital adipose body; C — lacrimal gland; D — gland of the third eyelid.





M. Węgrzyn *auctor phot.*





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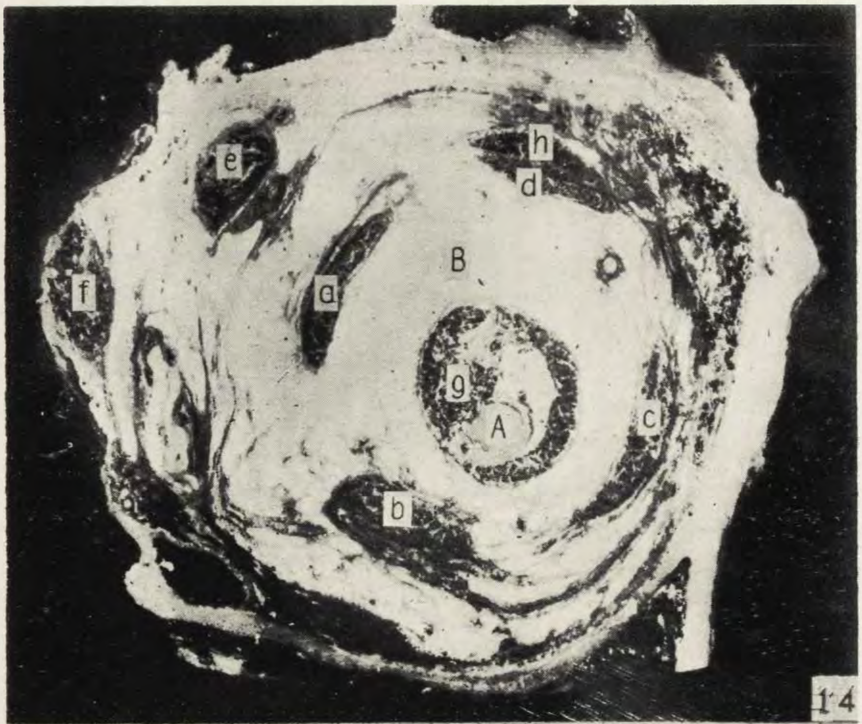

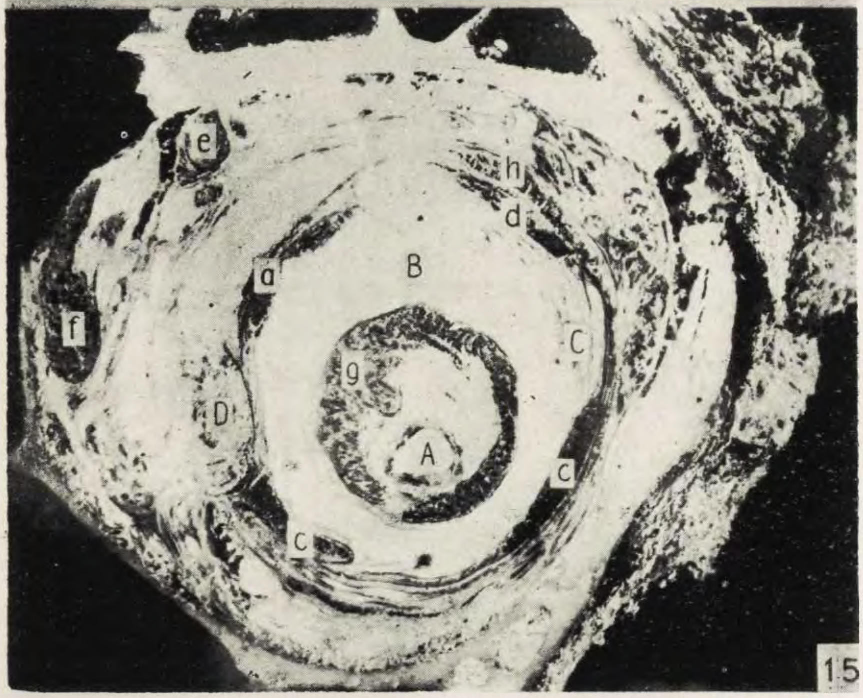

M. Węgrzyn *auctor phot.*