THE ANATOMY AND HISTOLOGY
OF
THE HUMAN EYEBALL
IN THE NORMAL STATE

ITS DEVELOPMENT AND SENESCENCE

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WITH 5 TEXT FIGURES AND 9 PLATES IN PHOTOCOLLOTYPE

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ANATOMIE UND HISTOLOGIE
DES
MENSCHLICHEN AUGAPFELS
IM NORMALZUSTANDE

SEINE ENTWICKLUNG UND SEIN ALTERN

Von

DR. MAXIMILIAN SALZMANN

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MIT 5 FIGUREN IM TEXTE UND 9 TAFELN IN LICHTDRUCK

LEIPZIG UND WIEN

FRANZ DEUTICKE

1912

Dedicated to My Revered Teacher
the Thorough Student and Investigator of the
Normal and Pathologic Anatomy of the Eye
PROFESSOR ERNST FUCHS
By the Author

PREFACE

As in the case with so many other books, this one has developed from the lectures which I have regularly given for years, and I only comply with an oft-expressed wish of my auditors when I put the substance of these lectures into print from the same point of view as the one by which I have allowed myself to be guided in the lectures.

This point of view is that a thorough knowledge of the normal anatomy and histology gives the most certain basis for the understanding of methods of clinical investigation and for judging pathologic changes—hence the reference to ophthalmoscopy, to the physiology of accommodation, and to pathologic processes here and there.

I should like to have the book considered from the point of view that it is the eye specialist and not the specialist in anatomy who writes it. For example, I have not gone into comparative anatomy in a detailed way. Important as this is for the determination of morphologic questions and much as I am personally interested in it, I hold it to be superfluous for the purpose at hand to enter into this branch of learning. Naturally, therefore, some details of cell-structure, nerve-endings, and the like, which for technical reasons one can study only on animals, are treated only briefly.

Probably no one will find fault with me because I have not encumbered the book with the ballast of a complete reference to the literature. Such would stand in no relation to the compass of the text, which I have made as compact as possible. Extended references to the literature are to be found in the most cited articles, especially in the corresponding chapters of the *Graefe-Saemisch Handbuch.* On the other hand, I will not deny that any choice from our enormously swollen literature is an arbitrary one. Forgiveness is herewith implored in advance from whomsoever feels slighted in this respect.

One cannot be original in a subject which has been so much worked in its entirety and in detail. Content and method of expression must necessarily move in the same paths as those to which the earlier works have held.

At the same time I feel I may say that I have not simply copied from others, but that my descriptions and my drawings have been made true to nature. I have borrowed only one drawing (Plate IX, 6) —from an embryologic work; all others are original and with very few exceptions prepared from my own specimens. In so doing I have striven throughout to bring forth concrete pictures, i.e., each drawing is a true representation of the preparation concerned. Only the general drawings of the eyeball of the adult and of the newborn are schematic. In Plate I (Taf. I) some details of the zonula and vitreous are drawn in from other preparations and Plate III, 2 is also a combination of various teased preparations of the same eye.

I express my especial thanks to the publisher for his friendliness and for the sacrifice occasioned by the nature of the reproduction of the drawings, as well as to the Art Press of M. Jaffé in Vienna for the careful preparation of the plates, which have reproduced the characteristics of the original drawings in the truest way.

THE AUTHOR

VIENNA
September, 1911

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PART I

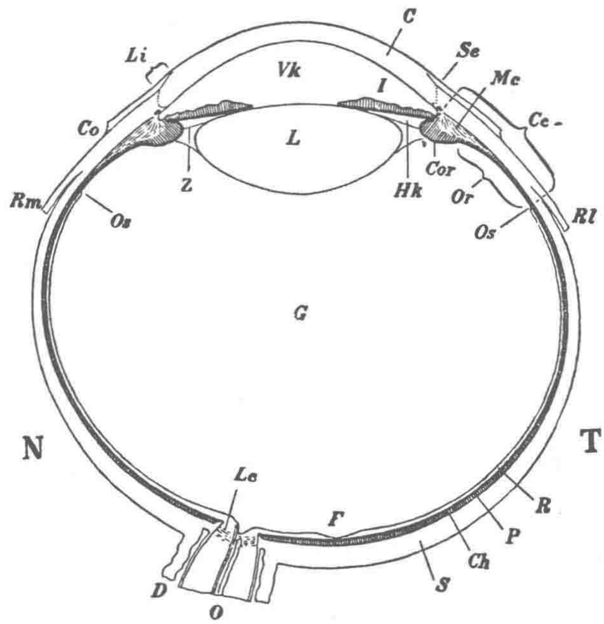
ANATOMY AND HISTOLOGY OF THE ADULT EYEBALL

A. THE EYEBALL AS A WHOLE (MACROSCOPIC ANATOMY)

I. Form, Size, Orientation

(Text Fig. 1)

The eyeball (*bulbus oculi*) on the whole has the form of a sphere, yet there are some variations from a pure spherical form.



TEXT FIG. 1.—Right eye, schematic horizontal section. Magnification 3.

N nasal, *T* temporal side, *Co* conjunctiva sclerae, *C* cornea, *Li* limbus, *Se* sulcus sclerae externus, *S* sclera, *Rm* musculus rectus medialis, *Rl* musculus rectus lateralis, *I* iris, *Cc* corpus ciliare, *Cor* corona ciliaris, *Or* orbiculus ciliaris, *Mc* musculus ciliaris, *Ch* chorioidea, *P* pigment epithelium, *R* retina, *F* fovea centralis, *Os* ora serrata, *Vk* anterior chamber, *Hk* posterior chamber, *L* lens, *Z* zonula ciliaris, *G* vitreous, *Lc* lamina cribrosa, *O* nervus opticus, *D* dural sheath.

To begin with, one notes a shallow, circular furrow in the anterior segment separating a smaller transparent area of about 12 mm in diameter (cornea, *C*) from the remaining white opaque portion (sclera, *S*). This furrow (*sulcus sclerae externus*, *Se*) is not prominent in profile view, for it is filled out for the most part by the *conjunctiva sclerae* (*Co*); one recognizes it better if one allows the image reflected from a mirror onto the anterior surface of the cornea to move toward the sclera. A narrowing of the image then occurs in the horizontal direction (Tscherning, 227) as the neighborhood of the margin of the cornea is reached and an elongation or a division into two images is seen after it actually passes over the margin of the cornea. The latter indicates the presence of a concavity in this location. This concavity is somewhat plainer on the nasal than on the temporal side.

The cornea is more sharply curved than the remainder of the surface of the eyeball. The foremost portions of the sclera are very weakly curved, and grade off very abruptly, almost conically, toward the equatorial portion, which again is somewhat more sharply curved.

The back half of the eyeball has a more uniform curvature than the front half, yet here, too, there are variations from the pure spherical form and I cannot accept the Merkel schema (151), which conceives of the form of the back half as that of a sphere.

In the first place, the **anatomic equator,** i.e., the sum-total of all those points maximally distant from the optic axis, does not go through an exact frontal plane, but lies farther forward on the nasal side, farther backward on the temporal side. Furthermore, the surface of the eyeball lying between the optic nerve and the nasal part of the equator is somewhat flattened, and the part lying temporal to the optic nerve is more strongly curved backward and outward.

The degree of this asymmetry varies much. In many cases it can only be made out by the accurate comparison of the profile of the eyeball with a circle of the same diameter; in many cases, however, it is so striking that one does not need any special means to recognize it.

24 mm may be looked upon as the normal **sagittal** or **long diameter** of the eyeball. The average of the dimensions given by various authors is as follows:

For the sagittal diameter 24.26 mm

For the transverse diameter 23.7 mm

For the vertical diameter 23.57 mm

The majority find the sagittal diameter to be the greatest, some, however, e.g., Leopold Weiss (235), the transverse; it is possible that racial peculiarities are responsible for this.

The limits within which the normal eye may vary have been determined, especially for the sagittal diameter, since this one is of the greatest importance in its relation to refraction. Schnabel and Herrenheiser (190) found an axial length of 22.5 to 26 mm in emmetropia. However, I doubt whether the upper limit is not carried too far, because, according to Elschnig (52), the form of the optic nerve entrance characteristic for the slightly myopic eye very frequently makes its appearance in such long emmetropic eyes.

Here as everywhere else the normal condition goes imperceptibly over into the pathologic, and the border line which one draws between the two is, necessarily, somewhat arbitrary and must have a position varying with the individual conception. In my opinion the finding of emmetropia does not in and of itself guarantee the normal structure of the eye. The normal form and the normal internal make-up of the eye must be considered as well; I need only to mention here the operated myopic eye, which can be emmetropic under favorable circumstances and yet possesses the anatomic evidence of high-grade myopia and all the weakness of such an eye.

The eyeball of a man is about 0.5 mm larger in all dimensions than that of a woman. Sappey (186) gives the following figures (in the same order as above):

For the eyeball of a man $24.6 \times 23.9 \times 23.5$ mm

For the eyeball of a woman $23.9 \times 23.4 \times 23$ mm

The weight, according to L. Weiss (235), is 7.5 g, the volume 7.2 cm^3.

For the orientation of the surface of the eyeball one makes use of the same constructions as on the surface of the earth.

The mid-point of the cornea determines the **anterior pole** of the eyeball. It lies diametrically opposite the **posterior pole,** which has no other anatomic characteristic, so can be found only by construction or measurement. The line of union between the two poles forms the **goemetric axis** of the eyeball.

It is well to distinguish this from the optic axis, i.e., the line upon which the focal points of the refracting surfaces lie, as well from the visual line, i.e., the line of union between the fovea centralis and the nodal point of the optic system. In the strict mathematical sense an optic axis exists only in the rarest instances, for the foci of the three most important refracting surfaces (anterior corneal, anterior and posterior lental) do not lie upon one and the same straight line at all as a rule (Zeeman, 244). The visual line bears away strongly from the geometric axis in any case, for the fovea lies temporal to and below the posterior pole.

If one measures the geometric axis from the anterior surface of the cornea to the posterior surface of the sclera, it may also well be called the **outer axis;** if, however, one measures only to the light-perceiving layer, i.e., to the outer surface of the retina, one calls this dimension the **inner axis.** It is this dimension which comes into consideration in the refraction of the eye.

Those circles which can be drawn through both poles are called **meridians;** the **equator** is that circle which is equidistant from the two poles.

This is the *geometric* equator and according to the above statements does not coincide with the *anatomic* equator.

A section through the vertical meridian divides the eyeball into a **nasal** or **medial,** and a **temporal** or **lateral** half. The expressions "inner" and "outer" should never be used in the sense of medial and lateral, but only as follows: **inner** is that which lies nearer the mid-point of the eye, **outer** that which lies nearer the surface. The expressions "forward" and "backward" do not refer to the sagittal direction alone but to the meridian as well: **forward** is that which lies nearer the anterior pole.

For example, the edge of the ciliary body bordering upon the trabeculum of the iris angle is called the anterior, that bordering upon the chorioidea, the posterior border, despite the fact that the difference in position in a sagittal direction is much less than in a frontal one. But if one were to refer to parts according to their actual position, the description would become extremely inconstant and confused.

Since we mainly make use of sections to illustrate anatomic relationships, it may be well to say something here concerning the direction of sections and what they are called.

The most important section direction is the **meridional,** i.e., a section in the plane of a meridian. Of the various meridians, the horizontal one comes mainly into consideration for anatomic purposes. It contains the most details, and **horizontal sections,** as they are called for short, are, therefore, the most instructive. Other meridians are only chosen for special purposes. **Frontal** or **equatorial sections** are sections parallel to the equatorial plane.

In most cases, however, a direction of sectioning must be chosen which does not coincide with any of these. In this case when the section is made at right angles to the meridian and at right angles to the surface of the bulb, I call it a **transverse section,** for it stands in the same relation to a meridional section of the area affected as does the cross-section to a longitudinal section.

When, on the other hand, the section falls parallel or tangential to the surface, it is called a **surface section.** Since, however, most of the surfaces of the bulb are curved, only tangential sections can be made, and in such sections the tissue is actually cut along the surface over only one small area; farther away from this place the sections become increasingly oblique (the same holds true for transverse sections).

For purely histologic purposes such surface sections are usually very useful, for even the area which is actually cut along the surface contains a very considerable number of tissue elements. On the other hand, surface sections are inadequate for anatomic purposes, in which the general view is more sought for, and must be replaced by **surface preparations,** i.e., by thin sections, which are only obtained by anatomic preparations.

Today there is a tendency to study sections only, because the modern staining methods lend themselves better to sections, and, indeed, sections give very beautiful and instructive pictures. Above all, the modern section methods contribute an incomparable amount to the topography. The older methods of anatomic preparation and the teased preparations do not, however, by any means deserve the disregard which they today receive. In the first place they show us the tissue elements in a much more