The Cause of the Wedge-shaped Cataract is Accommodation in Ages of Presbyopia.

Naomi Okuyama[1]
1) Director, Okuyama Ophthalmology Office, Yamagata City, Yamagata Prefecture. JAPAN

Key Words

Wedge-shaped Cataract, Human Lens, David G. Cogan, John Harding, Power of Accommodation, Presbyopia, Robert A. Moses, Edward Cotlier, Lens Capsule, R. F. Fisher, Young's Modulus of Elasticity, Lens Equator, Lens Epithelial Cell, Lens Fiber Cell, ATP, Mitochondria, Oxygen Partial Pressure, Pressure Gradient, Cell Membrane, Semipermeable Membrane, Lysosomal Enzymes, Half-life of Enzyme, Near Glasses, Cataract Surgery.

Abstract

On age-related cataracts, biochemical changes and changes of the shape were completely investigated. However, the causes were unknown. I believed that the answer to the cause of wedge-shaped cataracts must be hidden in those researchers` studies. I chased the cause of cataracts only by adding some logical consideration to the literature of preceding researches. I solved the riddle of cataracts. The cause of wedge-shaped cataracts is the crushing of the lens' epithelial cells by the pressure from the lens capsule in the advanced ages. And then I indicated how to prevent cataracts and keep good eyesight. Moreover, this paper can decrease cataract surgeries all over the world.

Introduction

Cataracts are the great cold case.

I write this paper in such easy words as general people having little knowledge of science can also understand. This is because cataracts are concerned with many fields of sciences, society, and people's daily lives. I took care not to use any word which is not in ordinary dictionaries containing about 80,000 words.

An eye doctor in the countryside attempted to clear up riddles of wedge-shaped cataracts. He had two clues. One was his own experience as an eye practitioner. The other was a document written by David G. Cogan.

I searched literature and thought about wedge-shaped cataracts. And then, I resolved the riddle of cataracts. As a result, people can prevent cataracts and related lens diseases. And moreover, this paper can reduce financial burdens in many countries, because this paper can decrease cataract surgeries all over the world.

Although I think it is very difficult to read this story of the complicated eye for people, please do not give up halfway.

Results

(1) Preparatory knowledge for people and about a method of our study

To people, cataracts are a single disease by which an eye becomes opaque. Subsequently the eye loses its visual acuity. However, there are many sorts of cataracts. They are congenital cataracts, age-related cataracts, diabetic cataracts, traumatic cataracts and etc.

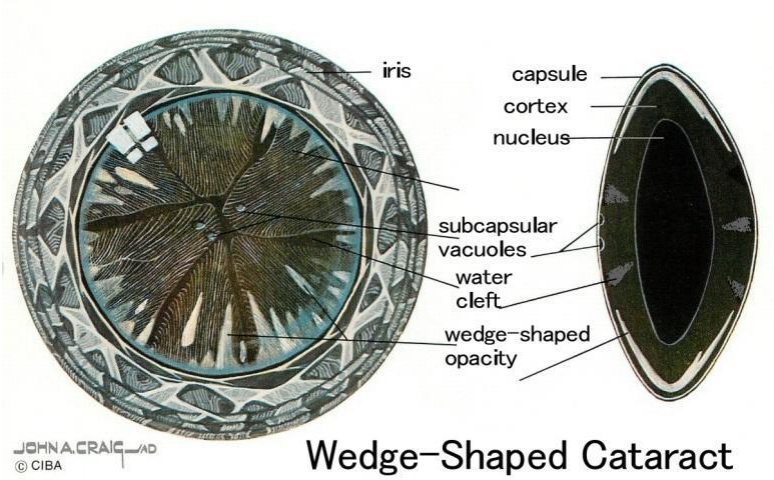
Among them, age-related cataracts are very important, because they affect so many people. The next three are the main types of age-related cataracts.

A. Wedge-shaped (Cuneiform) cataracts (Fig.1-1)

Wedge-shaped opacity begins near the equator of the lens cortex, and it progresses to the center of the lens. The word "opacity" means "opaqueness" or "an opaque area" in ophthalmology[1]. This is a common type of age-related cataract.

In the course of wedge-shaped cataract progression, other opaqueness, a large number of very fine opaque lines and speckled or dotted opaqueness occur.

Fig.1-1 Wedge-shaped cataract by David Paton and John A. Craig[2]



B. Nuclear cataracts (Fig.1-2)

In nuclear cataracts, the lens nucleus becomes gradually opaque and brown. In the lens, aged lens fiber cells accumulate toward the center of the lens. These accumulated cells make a lens nucleus. Because of this accumulation, the nucleus gradually increases in opaqueness and hardness. Therefore, everyone develops this cataract. However, only a small number of people lose eyesight due to this cataract.

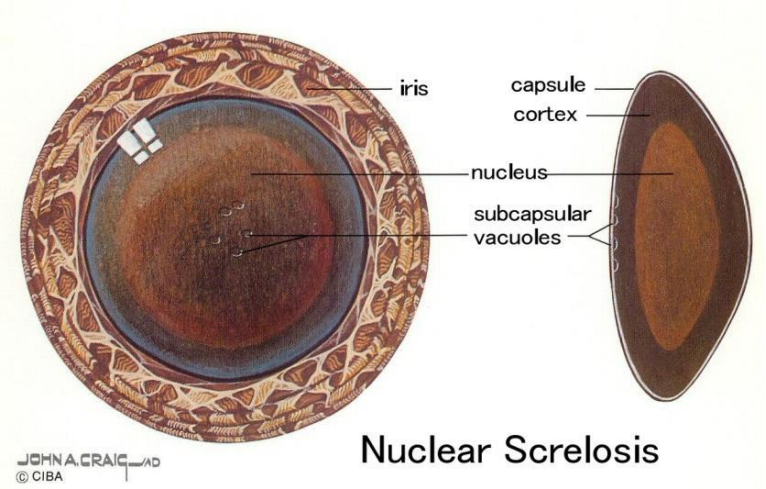
The cause of the brown color is AGE: Advanced Glycation End Products. John Harding says as follows in his book[3].

"In vitro non-enzymic glycation of proteins caused conformational changes to the proteins exposing the protein cores." "The proteins also became yellow and fluorescent and aggregated. The same alterations were seen in glycated protein isolated from human diabetic cataracts, and are changes known to occur in human cataract generally."

The “glycation” is “the result of typically covalent bonding of a protein or lipid molecule with a sugar molecule.”

This is the only age-related cataract in which the cause was explained clearly.

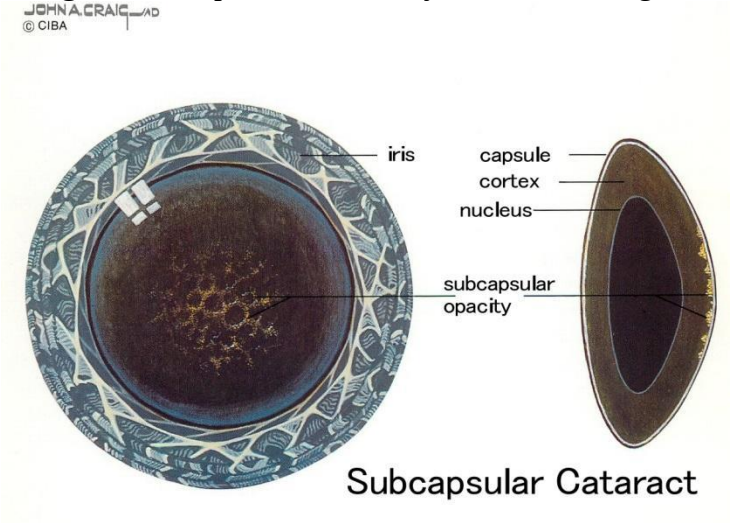
Fig.1-2 Nuclear cataract by Paton and Craig[2]



C. Subcapsular cataracts (Fig.1-3)

In subcapsular cataracts, opaque spots appear on the internal surface of the posterior lens capsule. The opaque spots increase gradually, causing loss of eyesight.

Fig.1-3 Subcapsular cataract by Paton and Craig[2]



Wedge-shaped cataracts are the most common and most important type of age-related cataract. Countless researchers have studied cataracts and age-related cataracts. However, the cause of wedge-shaped cataracts remains unknown.

In cataracts, opaque substances impair a person’s visual acuity. The studies on cataracts investigated up to today only discussed how the opaque substances are caused by biochemical changes. Those reports about biochemical changes in age-related cataracts investigated everything about lens substances in cataracts.

Harding describes as follows. “Not surprisingly the insoluble protein contains a wide variety of lens polypeptides.[3]” There are so many substances relating to cataracts. Among them insoluble proteins and insoluble aggregates are the final opaque products in cataracts. Many products come out from various origins, but none of those miscellaneous origins will be the primary cause of cataracts. Therefore, however researchers investigate those substances, no one will find the cause

of cataracts. They only go too far into the affair. Contrary to this, if anyone traces the process of the lens cell crushing, she will reach the cause of wedge-shaped cataracts, and she can explain the progression of wedge-shaped cataracts without any contradictions.

To write our conclusion first, biochemical changes of substances in wedge-shaped cataracts are not the cause of cataracts, but only the result. The cause of wedge-shaped cataracts is the crushing of the epithelial cells.

Changes of shape in age-related cataracts have already been investigated exhaustively as with the case of the biochemical changes. I believed that I could trace the origin of wedge-shaped cataracts by digging up literature reported up to now, and that the answer to the cause of wedge-shaped cataracts must be hidden in these researchers` studies.

This paper is written only by piling up facts and logic. The "facts" are the preceding literature of our excellent predecessors. The "logic" is my thought. I will dig up important literature from many studies. Then I will make obvious the cause of wedge-shaped cataracts based on that literature.

(2) Destruction of the human lens cell by the lens capsule

As soon as I started digging up previous literature, I found a document by David G. Cogan.[4] In the document, the answer to the cause of cataracts was written. It was revealed by the excellent researcher, David G. Cogan. He indicated that the beginning of wedge-shaped cataracts was crush of lens cells. In Cogan's paper, "Pathology of Age-Related Cataracts (1990)," the next sentences are described with a microphotograph.

"Balloon cell formation" (Fig.2-1)

"This type of formation is seen predominantly in the subcapsular region , especially conspicuous in the equatorial regions where a mosaic of balloon cells, with or without nuclei, occupy the region corresponding to the usual bow configuration (Fig.4). Occasionally clusters of balloon cells are also found deeper in the cortex suggesting that they have been displaced inward by the subsequent formation of new lens fibers.

A tentative explanation for the balloon cell metamorphosis is that the equatorial epithelium, unable to develop a fiber configuration, undergoes an aberrant maturation with increase in cytoplasm and loss of nuclei ; the cells form balls instead of fibers. Of course, this interpretation still leaves open the question of why the cells have lost their ability to differentiate into normal fibers in the first place.

The relation between the balloon cells and other forms of corticolysis is unclear. It seems likely, however, that as the balloon cells further disintegrate, that is, lose their cellular walls and become displaced inward, they metamorphose into the more obviously degenerate forms. Some of these clusters of balloon cells may become displaced into the deeper cortex by the generation of normal overlying fibers. It is also noteworthy that the process has a sectoral distribution corresponding to the spokelike configuration of the opacities seen in the gross specimen."

Corticolysis: "Cortico" means "pertaining to cortex" and "lysis" means "destruction, as of cells by a specific lysin.[1]"

Fig.2-1 Balloon cell formation by David G. Cogan[4]

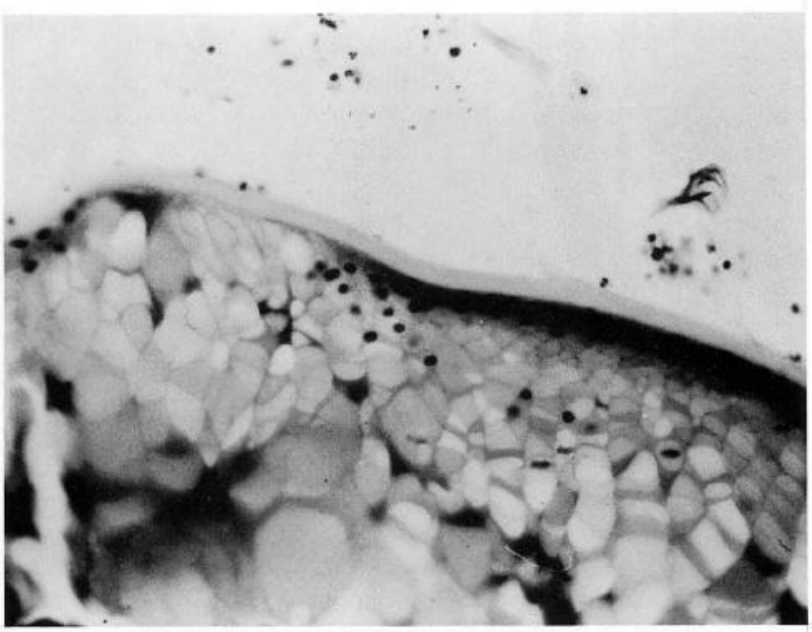


Fig. 4. Aberrant differentiation of lens fibers in the form of balloon cells at the equator (hematoxylin and eosin stain, ×250).

Without a doubt, this "balloon cell formation" is the beginning of wedge-shaped cataracts. I am convinced that the balloon cell is an initial indicator of lens cell being crushed.

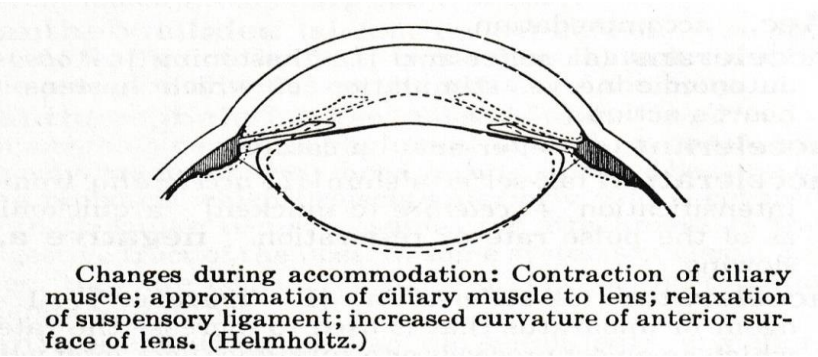
At the lens equator, pressure from the lens capsule has occurred. Therefore, the cause of wedge-shaped cataracts cannot be considered anything other than the pressure from the capsule. As it was assumed that the cause of wedge-shaped cataracts was the unnecessary pressure from the capsule during advanced age, for over past 20 years I strictly directed my patients to use reading glasses. As a result, I was able to stop the progression of wedge-shaped cataracts in almost all patients. I had been thinking that the cataract began as a simple crack of the lens cortex by the immoderate pressure. However, I found the literature of Cogan. His description was quite amazing. And it destroyed my view completely. I gave up the idea of a simple crack and restarted from Cogan's literature. From now on, I will call "the pressure from the capsule" "the PRESSURE."

(3) Accommodation causes destruction of a human lens.

1. A somewhat deep understanding of accommodation of the eye

The word "accommodation" in ophthalmology means "adjustment, especially that of the eye for various distances (see illustration).[1]" The word "accommodation" generally means "a place for someone to stay." In this paper, I use only the word "accommodation" in the specialized meaning. I try not to use other words such as "accommodative," "accommodate." By the way, now I am planning to stay in Göteborg at a hotel which accommodates only twenty guests.

Fig.3-1 Changes during accommodation[1] from DORLAND'S ILLUSTRATED MEDICAL Dictionary



Changes during accommodation: Contraction of ciliary muscle; approximation of ciliary muscle to lens; relaxation of suspensory ligament; increased curvature of anterior surface of lens. (Helmholtz.)

John Parr describes the lens. (Fig.3-1) "The lens provides the adjustable part of the eye's refractive power. It lies behind the aqueous and in front of the vitreous ; together with its suspensory zonule and the ciliary body." "It is about 9 mm in diameter, about 5 mm thick.[5]" Vitreous : Glasslike or hyaline; often used alone to designate the vitreous body of the eye.[1] Vitreous body: The transparent gel that fills the inner portion of the eyeball between the lens and the retina.[1] Ciliary body: The thickened part of the vascular tunic of the eye.[1] Zonule: A ciliary fiber.[1]

Robert A. Moses explains the mechanism of accommodation of an eye, as follows.

"The lens capsule tends to mold the lens to a spherical shape, but this is opposed by the tension of the zonular fibers that suspend the lens from the ciliary body. Traction of the zonule on the lens capsule flattens the lens. The ciliary body is stretched backward and outward along the sclera by the elastic choroid. Contraction of the ciliary muscle pulls the choroid forward and the ciliary attachment of the zonule inward toward the lens, reducing the tension in the zonule and allowing the lens to increase in convexity," and "increase in convexity of the lens increases its dioptric power and allows near objects to be imaged clearly on the retina.[6]" (Fig.3-2)
Sclera: The tough white outer coat of the eyeball.[1] Choroid: The thin, pigmented, vascular coat of the eye.[1] Dioptric: To more convex shape. Zonular fiber: Zonule.[1]

The zonula, or the ciliary fibers, are in the zonular spaces. (Fig.3-3) The ciliary body links to the choroid which is located between the sclera and the retina. The ciliary muscle in the ciliary body surrounds the lens like a ring.

Fig.3-2 The ciliary muscle by Robert A. Moses[6]

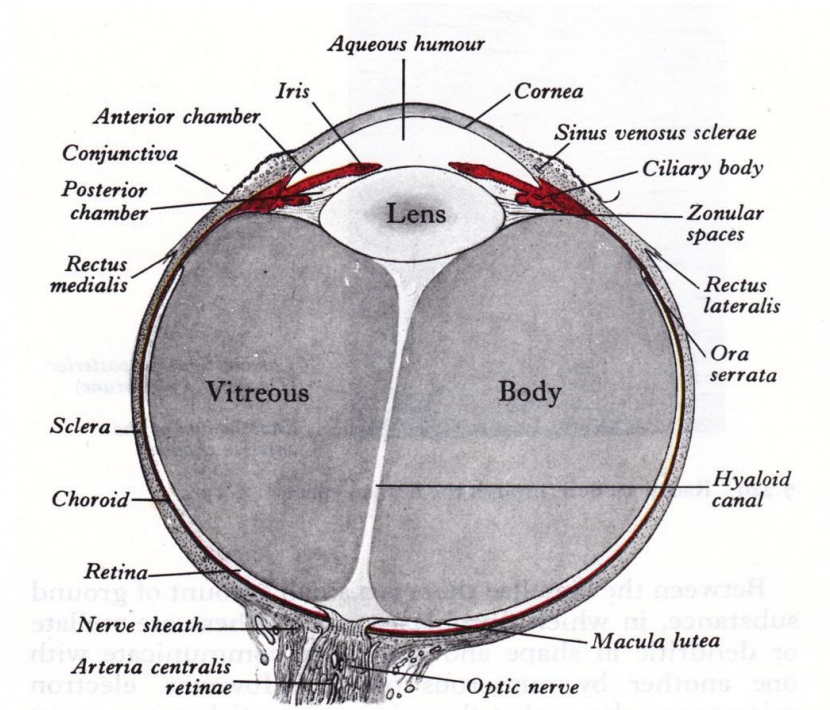
Fig. 11-9. Internal part of ciliary muscle. (From Fincham, E.F.: Br. J. Ophthalmol. Monogr. Suppl. **8,** 1937.)

If the muscle tenses, the ciliary fibers relax. Accordingly, the thickness of the lens increases. As a result, the eye is focused on a nearby object. In the state of accommodation, the powerful ciliary muscle pulls the choroid toward the lens. The whole of the ciliary body itself moves toward the

lens with the choroid. (Fig.3-2)

If the muscle relaxes, the ciliary fibers tense. Accordingly, the lens flattens. As a result, the eye is focused on a distant object. In non- accommodation, the choroid pulls the whole of the relaxed ciliary body and the powerful capsule via its strong contraction.

Fig.3-3 A horizontal section of an eyeball by Moses[7]



7.247 A horizontal section through a right human eyeball. Superior aspect.

It is necessary to understand the structure of a human lens. (Fig.3-4) The capsule envelopes the entire lens. An epithelium of the lens is beneath the anterior capsule, but no epithelium is under the posterior capsule. The cortex of the lens is composed of lens fiber cells. The center of the lens is the nucleus. The cortex envelops into the nucleus.

Anterior epithelium cells repeat cell divisions over again, and they advance toward the equator of the lens by degrees. Around the equator, the epithelium cell begins to transform into a fiber cell. In the process of transformation, the cell loses mitochondria and other organelle.

Mitochondria: Small spherical to rod-shaped components found in the cytoplasm of cells They are the principal sites of the generation energy (ATP).[1] Organella: A specific particle of membrane-bound organized living substance present in practically all cells.[1] ATP: adenosine triphosphate, a nucleotide compound occurring in all cells, where it represents energy storage.[1]

Fiber cells lose those nuclei finally. In this course fiber cells go deep into the cortex by degrees. In this way, the lens fiber cells go on accumulating toward the nucleus.

Fig.3-4 The lens by Richard S. Snell and Michael A. Lemp[7]

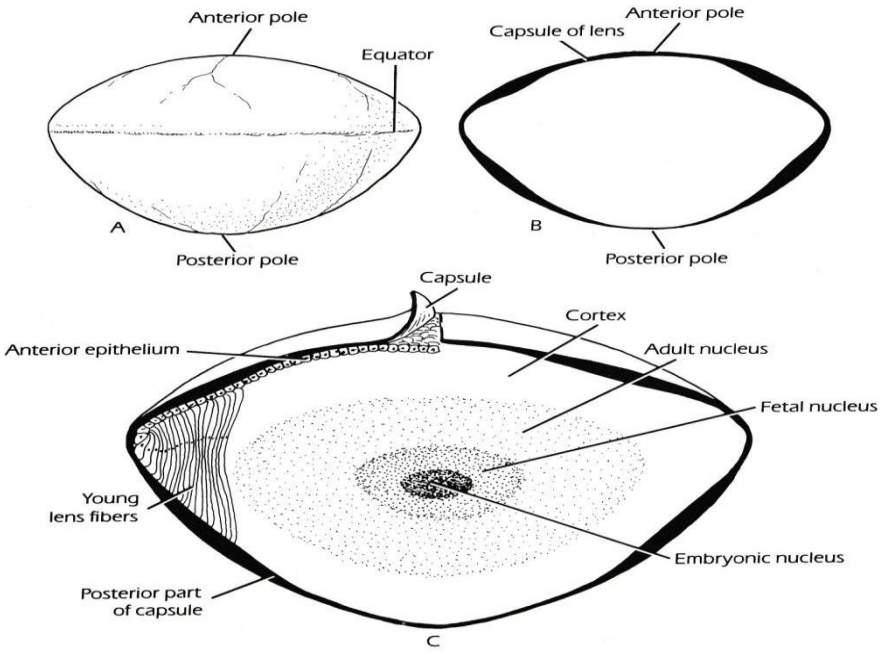


FIGURE 6•43

(A) Diagram of the lens in equatorial view. (B) Diagram of the lens capsule, showing its areas of thickening. (C) Diagram of a section of adult lens, showing the various lens nuclei within the lens cortex.

Ciliary fibers attach to the equator region of the capsule. Because of the strong elasticity of the capsule, when the zonule relaxes, the thickness of the lens increases. The capsule tends to warp by its own elasticity. Ciliary fibers attach to the ciliary body between the ciliary processes.[7]

We do accommodation unconsciously. When we look at an object naturally, there must be no problem for the accommodation. However, in some conditions, problems arise with the accommodation. Because of it, the eye will be destroyed. I named that "prohibited accommodation."

I think there are two kinds of prohibited accommodation. I called the first prohibited accommodation "excessive accommodation." I named the second "unreasonable accommodation."

2. "Excessive accommodation"

This is the accommodation when a person looks at an object at a distance nearer than 30 cm at an age under about 40.

The distance of 30 cm, or about 1 foot, is a very important distance for an eye. When an eye looks at an object at this distance, its accommodation power of 3.3 diopters is used. The power of 3.3 diopters of the eye is converted into 3.0 diopters of spectacles optically. "Diopter" is "the refractive power of a lens with a focal distance of one meter.[1]"

That is,

Diopter = 100 cm / focal length cm

From now, we use the abbreviation D for the unit of "diopters." In a myopic eye, the (-) sign is put before the number of diopters. In case of a small number of farsighted eyes, the (+) sign is put before the diopter number. Since near vision is talked about in this paper, the (+) sign is put before all numbers of diopters. But I will omit all those signs.

At the distance of 30 cm, the eye can see the detail of the object sufficiently, because it is not too distant. Besides, the eye can get enough of the area of the near object into view, because the distance is not too near. It is a suitable distance for the eye to see a wide area of the near object.

The distance of 30 cm is the perfect distance to see nearby objects in both minute detail and as the whole. Therefore, the distance of 30 cm must be a very important distance for the eye.

When the eye looks at an object nearer than 30 cm, it uses accommodation power of more than 3.3 D. This is "excessive accommodation." From now on, we will refer to "excessive accommodation" as "EXCESSIVE."

3. "Unreasonable accommodation"

This is the accommodation in the age of presbyopia when a person looks at an near object at a distance of 30 cm or more without proper reading glasses. In the reprinted diagram Fig.3-5, maximum accommodation power decreases with age. The "amplitude of accommodation" in Fig.3-5 means the range of the maximum accommodation power at each age, and the "mean" in the diagram is median maximum accommodation power. I added a line labeled 3.3 D to the original diagram Fig.3-5. From now on, we will refer to "accommodation power" as "POWER."

At the age of 41, if the eye still has a maximum POWER of more than 3.3 D, the eye can still look at an object at the distance of 30 cm. However, if at the age of 41 the eye has a low maximum POWER of just 3.3 D, then it can barely see an object at the distance of 30 cm. After that age, the POWER continues decreasing. Presbyopia is the situation where an eye cannot see an object at the distance of 30 cm or less. I define presbyopia as this. Therefore, we call the age of 42 or older, "the age of presbyopia."

Fig.3-5 Amplitude of accommodation by Robert A. Moses[6]

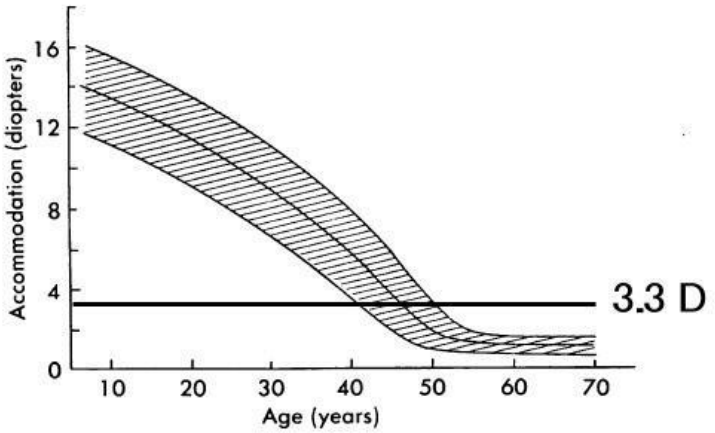


Fig. 11-19. Amplitude of accommodation, showing range found in population and mean. (From Duane, A.: Arch. Ophthalmol. **54:**568, 1925.)

The maximum POWER at each age will never mean always permissible volume of accommodation. In Fig.3-5 by Robert A. Moses, for example, the median maximum accommodation power at the age of 20 is 12 D. But, if a 20-year-old person continues looking at objects using a POWER of 12 D, her eye's load gets extremely heavy. This is because 12 D is the power an eye uses when it looks at an object at the distance of only 8 cm. The normally usable POWER is considered at most 3.3 D. From now on, we will call the "median maximum accommodation power" "MmPOWER."

In Fig.3-5, the power of accommodation decreases rapidly with age. At the age 46, the MmPOWER falls to about 3.3 D. After that age, the power of accommodation decreases more, and at the age of 50, the MmPOWER decreases to 2.0 D far less than 3.3 D. When we see how human POWER decreases, it is conceivable that the expected life span of the human lens is about 50 years.

In the age of presbyopia, the accommodation to look at an object at the distance of 30 cm or less is “unreasonable accommodation.” At an age over 41, we should not use this “unreasonable accommodation.” This causes problems for the eye. Even if the eye attempts this “unreasonable accommodation,” it cannot accomplish accommodation. The eye only uses its power, and it is unable to see the object which it has attempted to see. Therefore, I call the power the “unreasonable power of accommodation.” This causes problems.

4. The first incident brought about by the EXCESSIVE: Worsening of myopia

In diagrams Fig.3-6 and 7, arrows indicate the pressure on the lens caused by the capsule. In the EXCESSIVE, as an eye looks at an object at a distance nearer than 30 cm, the lens capsule presses the lens excessively. The pressure working in this accommodation is “excessive pressure.”

Fig.3-6 The lens capsule presses the lens. (a side view)

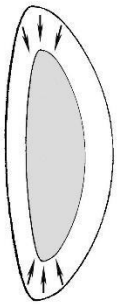
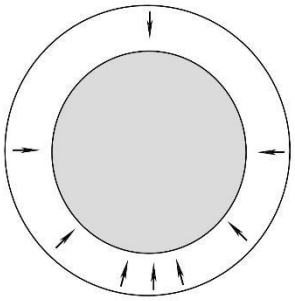


Fig.3-7 The lens capsule presses the lens. (a front view)



Pressure has no direction, it only has strength. But in most cases in this paper, I use the word “pressure” as a pressing power which has a direction.

In a human lens, the nucleus gets harder with age. Accordingly, it gets difficult to return from the state of increased convexity by near vision. As a result, myopia of the eye gets worse. This process is the cause of worsening of myopia at the age of 16 or older.

In childhood, between the ages of 6 and 15, myopia worsens because the length of the eye ball increases with age. It is only growth of the eye. Including age-related cataract and myopia, the affairs which concern human lens are full of riddles. Therefore, the investigation of myopia is in chaos, like with cataracts. I think the cause of worsening of myopia in a person over the age 15 is the change of the lens shape by the EXCESSIVE. If the refractive power of a human lens increases drastically from the excessive PRESSURE, in the situation that a lens nucleus hardens, it becomes difficult for the lens to return to the original shape. I think this is adult myopia. In this way, the EXCESSIVE worsens the myopia.

5. The last result of the EXCESSIVE：The “distorted lens”

The lens nucleus becomes hard with age. KR Heys said as follows. "There was a pronounced increase in lens stiffness over the age range from 14 to 78. In the nucleus, stiffness values varied almost 1,000 fold over this age range, with the largest change observed in lenses between the ages of 20 to 60.[8]" The lens nucleus goes on stiffening steadily with age. By the EXCESSIVE, if the convexity of a human lens continues to increase for a long period of time, adult myopia worsens and, last of all, the lens loses the shape of an optical lens. It is what I call a "distorted lens". In this state, the shape of the lens has been broken down, and it is in the terminal point of adult myopia. Because the lens cannot be focused on anything, the eye will not get enough sight even if corrected by eyeglasses.

It is assumed that when a change of the lens shape has gone beyond its limit by the worsening of myopia, a "distorted lens" occurs. This comes after the lens had become hard to change the shape for seeing near objects. When an eye develops a "distorted lens" by the EXCESSIVE, as the eye seems to have no remarkable disorder, ophthalmologists diagnose the eye's low vision as "an unknown cause." And next, the ophthalmologist diagnoses the low vision as nuclear cataract. The eye will be operated as a cataract.

We must avoid the EXCESSIVE.

Fig.3-8 Human lens growth with age by Harding[3]

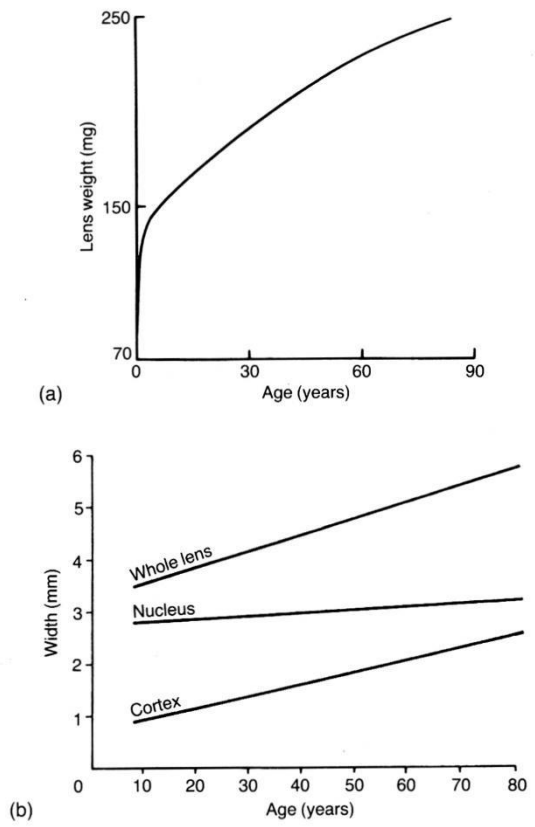


Figure 1.3 Human lens growth with age: (a) weight; (b) thickness.
Taken from Harding, Rixon and Marriott (1977) and from Brown (1976).

Although the size and volume of a human lens changes with age, it is strange that the lens seems to keep its shape and that the degree of refraction does not alter with age. (Fig.3-8)

The "distorted lens" comes about mainly by the EXCESSIVE, and the unreasonable power of

accommodation also leads to this state. From now on we call the "unreasonable power of accommodation" "UNREASONABLE POWER." We consider the cause of the "distorted lens" in the age of presbyopia is the UNREASONABLE POWER.

After the age of 60, in a human lens which cannot get enough visual acuity, a border between the lens cortex and the nucleus sometimes forms a bumpy, brown membrane. I think it is the wrinkled surface of the nucleus. It must be a symptom of the "distorted lens." It suggests that even a considerably hardened nucleus has been distorted by the PRESSURE. Thus, the PRESSURE destroys the lens.

6. The UNREASONABLE POWER causes wedge-shaped cataract.

<The power of the ciliary muscle>

After the nucleus has increased stiffness with age to a certain degree, the UNREASONABLE POWER begins to cause an incident other than the "distorted lens." This is the "destruction of the lens." It is the wedge-shaped cataract.

The lens cortex is sandwiched between the capsule and hardened nucleus. If an eye at the age of presbyopia looks at an object at the distance of about 30 cm without reading glasses, the lens cortex is pressed by excessive power from the capsule. This power is the UNREASONABLE POWER.

The lens nucleus continues becoming increasingly stiff, meanwhile the power of the capsule, or the elasticity of the capsule, decreases with age. Though, it is conceivable that the ciliary body keeps its power through the life. In this situation, even if the ciliary muscle tenses excessively, the required change to a more convex shape of the lens cannot be accomplished.

Moses writes as follows.

"Measurements of ciliary body movement in accommodation appear to show that the same movement is required per diopter of accommodation at all ages tested.[6]"

E.A. Hermans et al. wrote as follows. "Preservation of the net force delivered by the extralenticular ciliary body indicates that the causes of presbyopia must be ascribed to lenticular changes.[9]" Lenticular: Pertaining to the crystalline lens.[1]"

The power of the ciliary muscle does not decrease.

<The power of the capsule>

R. F. Fisher states, "in childhood Young's Modulus of elasticity is about 6 x 10^7 dyn/cm^2 and decreases to 3 x 10^7 dyn/cm^2 at 60 and 1.5 x 10^7 dyn/cm^2 in extreme old age.[10]"

Although the elasticity of the lens capsule decreases with age, the power of the capsule will be strong.

<The power of the capsule at the age 8 and at the age 60>

The Young's Modulus of elasticity value at the age of 60 is 3 x 10^7 dyn/cm^2. The value at the age of 8 is about 6 x 10^7 dyn/cm^2. We assume the child is 8 years old. In the diagram Fig.3-5 by Moses, the MmPOWER at the age of 8 is about 14 D. It is conceivable that if the lens does not increase in stiffness, the MmPOWER might be in proportion to the Young's value at each age. Therefore, as the value at the age of 8 is about 6 x 10^7 dyn/cm^2 and that at the age of 60 is 3 x 10^7 dyn/cm^2, if the MmPOWER at the age of 8 is about 14 D, the MmPOWER at the age of 60 must be 7 D.

If the lens does not increase in stiffness, a person at the age of 60 must be able to look at an object at the distance of 14 cm with the power of 7 D. Though, in the diagram Fig.3-5, at the age of 60 the real power of accommodation is almost zero. This fact says that, although a 60-year-old eye cannot look at an object at the distance of 30 cm, the eye uses the maximum power of accommodation of 7 D. This power will destroy the eye. This is the UNREASONABLE POWER.

<The UNREASONABLE POWER works on the equator.>

In the eye of the age of presbyopia, the accommodation corresponding to the power does not work. But the power of accommodation continues to be used by the capsule. This power is the UNREASONABLE POWER. In a young eye, the pressure put on the lens in accommodation will disperse into the whole of the lens. This is because the lens of a young eye is still soft. However, the lens of an aged eye has become hard. Therefore, in the aged eye, the cells on the equator receive all of the pressure.

Wedge-shaped cataracts occur in such circumstances. The immoderate PRESSURE, or the UNREASONABLE POWER brings about crush of the cells on the equator.

(4) How does the PRESSURE work on the lens?

1. The UNREASONABLE POWER

By the UNREASONABLE POWER, all phenomena of wedge-shaped cataract begin as a collapse of the cell on the equator.

2. Parts of the lens which receive the destructive power

<Pressure[a]>

The PRESSURE presses the cells on the equator directly. This pressure proceeds to the center of the nucleus. The cells are sandwiched between the capsule and the nucleus. If I say this more correctly, those cells are sandwiched between the capsule and the cortex. We refer to this pressure as “Pressure[a].” (Fig.4-1, 4-2)

Fig.4-1
Pressure[a] (a front vie)

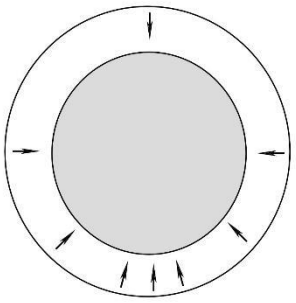
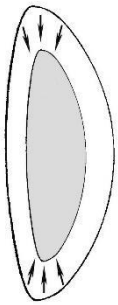


Fig.4-2
Pressure[a] (a side view)

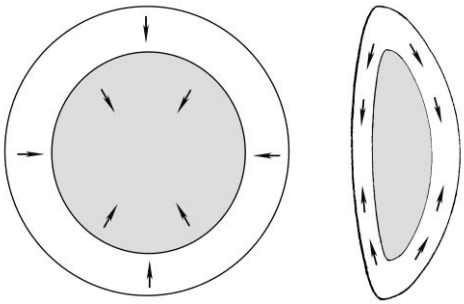


<Pressure[b]>

The PRESSURE put on the lens equator travels through the layers of lens fiber cells to the regions of the anterior and posterior poles. This pressure does not proceed to the center of the nucleus, only passes through fiber cells. Lens fiber cells are not caught by this pressure. We refer to this pressure as “Pressure[b].” (Fig.4-3, 4-4)

Fig.4-3
Pressure[b] (a front view)

Fig.4-4
Pressure[b] (a side view)

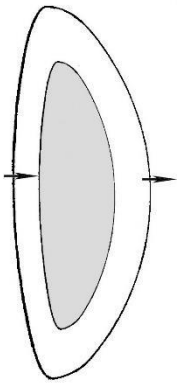


<Pressure[c]>

The capsule puts the pressure on epithelial cells and fiber cells in the anterior polar region. I think in the posterior polar region that the capsule provides the lifting power to the lens cortex, not the pressure. We refer to this lifting power as "Pressure[c]." (Fig.4-5)

Fig.4-5

Pressure[d] (left arrow) Pressure[c] (right arrow)



<Pressure[d]>

In the anterior polar region, the capsule receives pressure from the lens cortex which is pushed forwards by Pressure[a] and Pressure[b]. At the same time, the anterior capsule presses the epithelial cells and cortex towards the nucleus as repulsion. We refer to this pressure as "Pressure[d]." Due to this pressure, epithelial cells around the anterior pole are sandwiched between the capsule and the cortex. This pressure is repulsion for Pressure[a] and Pressure[b]. (Fig.4-5)

3. Collapse of the cells on the lens equator: "Balloon cell formation"

<The balloon cell formation>

This is the first of three types of histopathologic changes in cortical cataracts which David G. Cogan listed.[4] (Fig. 2-1, 4-6) This is the first stage of the lens collapse. He describes the state as if epithelial cells grow normally to lens fiber cells on the cell's own way around the equator. He is aware of unusual changes of cells on the equatorial region. But he describes as follows, "why the cells have lost their ability to differentiate into normal fibers in the first place.[4]" He cannot explain the cause of the change. The sight "balloon cell formation" which Cogan observed is the appearance of dying cells in the equator.

Fig.4-6 Balloon cell formation by David G. Cogan[4] (The same as Fig.2-1)

Fig. 4. Aberrant differentiation of lens fibers in the form of balloon cells at the equator (hematoxylin and eosin stain, ×250).

Until I began to write this paper, I thought that wedge-shaped cataract started with the simple mechanical crack of the lens cortex. But immediately after I started to write, Cogan's description came out and contradicted our thoughts entirely. Though, I had experiences. For over 20 years, I could stop the progression of wedge-shaped cataracts by proper reading glasses for prevention of the UNREASONABLE POWER in almost all patients. Therefore, I was convinced the balloon cell formation which Cogan showed must be the start of wedge-shaped cataract.

<What mechanism does work on the crush by the pressure?>

It is known that epithelial cells lose mitochondria, other cell organelle and nucleus of the cell last in the way of transformation into fiber cells to the deep cortex, in the same way as red corpuscles.[11] In this course, the epithelial cell gets "deformability," or the "ability of a cell to change shape[1]" and pressure resistance.

I do not know which cell is crushed in the equator. Is it the epithelial cell or the fiber cell? For the time being, we will call the cell "the cell on the equator". Why is the cell on the equator crushed to death? The conceivable mechanisms of this crush by Pressure[a] are the next three items.

A. A simple mechanical rupture: This rupture does not occur. No one observed this.

B. The pressure injures organelle or cell components directly.: It is inconceivable that the organelle or the cell components suffer some mechanical injury from the pressure directly. It is also inconceivable that cell functions stop from the pressure directly.

C. An accident by an unknown mechanism occurs to the cell other than A and B.: Due to the unknown mechanism from the pressure, the cell is crushed. Because of the mechanism, the cells are crushed on the equator. This unknown mechanism must be the cause.

The phenomenon which Cogan showed occurs at the equator. It is the mass death of the cells, obviously. If someone sees that such a phenomenon occurs at the equatorial region, she will think that just the PRESSURE might be the original cause, as I did. I was convinced that the unknown

mechanism by the PRESSURE was the principal offender and that it was the root of wedge-shaped cataract.

If someone sees that the large-scale death of cells due to the pressure occurs, first he will hit on a shortage of oxygen caused by the pressure. This is because the scale of the death of cells is large and happens at one time. The cells on the equator are sandwiched between the capsule and the cortex. In the cortex, under the sandwiched cells, progressed fiber cells have increased their hardness like the nucleus. Due to the PRESSURE, internal pressure of the sandwiched cell will have increased on the equator. To the human lens, aqueous humor and vitreous fluid are the source of all nourishments, including oxygen and glucose. Therefore, it is thought that owing to the high internal pressure in the cell, permeation of oxygen from the aqueous humor and the vitreous fluid into the cell falls. If oxygen partial pressure falls in the cell, we think the activity of mitochondrion also falls due to the lack of oxygen. As a result, supply of ATP into the cell decreases, and all organs in the cell stop their activities.

Then the cells will begin death with the passing of time. Wedge-shaped cataract begins. This is my hypothesis on the cause of wedge-shaped cataract.

<The shortage of oxygen and insufficiency of ATP>

If the supply of ATP decreases in the cell, the cell membrane will be affected first and drastically. J. David Rawn states as follows.

"The plasma membranes of animal cells maintain an intracellular K(+) concentration of about l40 mM in the presence of an extracellular K(+) concentration of about 5 mM." "The pump that maintains this imbalance is the *Na*(+)-*K*(+) *ATPase*, an ATP-driven antiport system that pumps two K(+) ions into the cell and ejects three Na(+) ions for every molecule of ATP it hydrolyzes. Each molecule of the Na(+)-K(+) ATPase hydrolyzes about 100 molecules of ATP per second under optimal conditions. About a third of the total energy requirement of the cell is used to drive the Na(+)-K(+) ATPase; in electrically excitable cells, the Na(+)-K(+) ATPase consumes 70% of the cell's energy.[12]"

If the supply of ATP into the cell decreases, the cell membrane will stop functioning first. Accordingly, the cell accumulates Na(+) ions and then gradually expands. This is the formation of the balloon cell.

I think insufficiency of ATP owing to the shortage of oxygen causes the large-scale death of cells. What change occurs in the cell on the equator due to the PRESSURE?

<The shortage of oxygen by some change of the cell membrane and the capsule>

We try to examine whether the cell membrane causes the shortage of oxygen or not.

Molecules of oxygen pass a lipid bilayer of the cell membrane by passive transport. It is inconceivable that the passages in the lipid bilayer of cell membranes are closed by the pressure. It is hard to consider, even if the pressure is 10 or 100 atm.

Lipid bilayer: A structure of the cell membrane. Passive transport: A way by which substances cross through cell membranes without metabolic energy. Atm: A unit of atmospheric pressure, the abbreviated form of atmosphere. 1 atm is 1013 hPa.

It is the same with the capsule. Any change of the cell membrane or the capsule will not cause the shortage of oxygen due to the pressure.

<The shortage of glucose>

We try to examine whether a shortage of glucose brings about the insufficiency of ATP or not.

Glucose passes the lens capsule by diffusion. "Diffusion" is another kind of passive transport. Substances pass the membrane via diffusion.

Brian P. Danysh et al. described as follows. “Smaller molecules required for cell metabolism such as glucose, salts, water, O, CO, and the resulting metabolic waste all pass freely through the capsule and into the cortex and nucleus of the avascular lens.[13]” It is inconceivable that passages in the capsule are closed due to the pressure. Even if the pressure increases to 10 or 100 atm, the structure of the lens capsule will not be compressed so tightly as to close the passageway. The capsule does not prevent the diffusion of glucose. It is the same with the capsule in the equatorial region where zonula insert. In that region, the structure of the capsule is different from other parts.[13]
Avascular: Not supplied with blood vessels.[1]”

Glucose passes the cell membrane by facilitated diffusion into the cell. It is also inconceivable that high pressure affects the facilitated diffusion in the cell membrane. This is because high pressure will not affect the lipid bilayer of the cell membrane through compression as with the capsule. It is thought that the shortage of glucose is not caused by high pressure.
Facilitated diffusion: The transportation of substances across the cell membrane by protein molecules.

<Insufficiency of ATP>

Furthermore, we try to examine the insufficiency of ATP. There are two causes which can bring about an insufficiency of ATP in the cell. The first is a relative shortage of supply because of an increase in consumption of ATP. The second is a shortage of supply owing to a decrease of ATP production.

<The increase in consumption of ATP>

Since an epithelial cell transforms into a fiber cell at the equator, there is the possibility that the increase in consumption of ATP occurs in the cell. However, it is not conceivable. If the shortage of ATP is caused by the increase in consumption, the transformation of epithelial cells into fiber cells simply stops. A relative shortage of supply because of an increase in consumption of ATP does not come about.

<The decrease of ATP production>

The possibility left last as the cause of the insufficiency of ATP is a shortage of supply owing to a decrease of ATP production. Two cases are conceivable as the causes of this. The first is direct injuries to mitochondria by the high pressure in the cell. The other is a decrease in the oxygen partial pressure by the high pressure in the cell. About the first, it is inconceivable. This is because deep-sea fish live without any trouble in the sea under hundreds of atm owing to the activity of mitochondria.

<The decrease of the oxygen partial pressure in the lens cell>

The decrease of ATP production must be the cause of the insufficiency of ATP.

The possible origin as the causes of the decrease of ATP production left last of all is the decrease of the oxygen partial pressure in the cell.

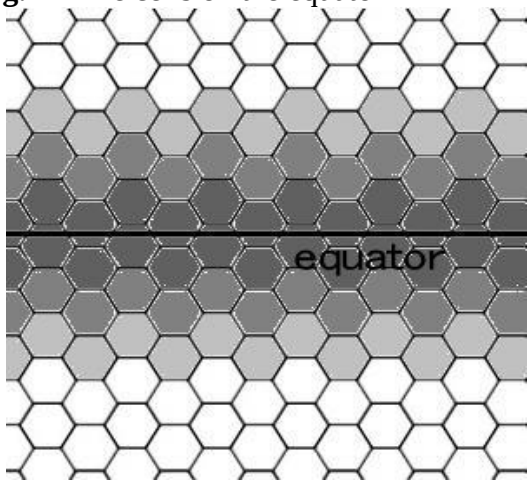
Why the oxygen partial pressure in the cell decreases due to the high pressure?

Henry’s law cannot be applied to this circumstance. The deep sea under the high pressure is different from this circumstance.

The answer is in the lens equator. The cells on the equator make single layer. Those cells receive the PRESSURE. In the equator, this pressure cannot diffuse sideways or downward. This is most important in thinking about wedge-shaped cataract. On the equator to sideways directions, those cells crowd densely and are surrounded by the same kind of cells. (Fig.4-7) In the downward direction, those cells are on a mass of hardened fiber cells. Consequently, the cells on the equator cannot slide sideways or move downward. Therefore, since the pressure cannot

diffuse sideways or downward, all of the pressure presses on the cells sandwiched between the capsule and the mass of hardened fiber cells on the equator. Depending on how a cell is located away from the equator, the pressure which the cell receives gradually becomes weaker. For this reason, the internal pressure of cells on the equator is higher than that of cells removed from the equator. A pressure difference arises here.

Fig.4-7 The cells on the equator



The pressure difference causes a decrease in oxygen, and the decrease in oxygen causes a decrease of ATP production, then, the cells on the equator die.

<The pressure gradient occurs by pressure difference. >

It is very important that only the internal pressure of cells in the equatorial region is high, whereas the internal pressure of the surrounding cells and the pressure in the aqueous humor are not high. In this equatorial region, a pressure gradient occurs by pressure difference.

The phrase “pressure gradient” we use is different from the “pressure gradient” in hydrodynamics or meteorology. We use the phrase to mean a phenomenon about a semi permeable membrane. When two independent spaces of different pressure sandwich a semi permeable membrane, the pressure gradient occurs between those spaces. This is because the pressure difference is there. The environment of the lens equator will be the same as the artificial semi permeable membrane. The pressure gradient starts to work in the cells on the equator in the same way with the semi permeable membrane.

Semi permeable membrane: A membrane that permits the passage of a solvent, such as water, but prevents the passage of a solvent of the dissolved substance, or solute.[1]

<How much pressure is put on the cells on the equator?>

Again, we see the description by R. F. Fisher. “In childhood Young's Modulus of elasticity is about 6 x 10^7 dyn/cm^2 and decreases to 3 x 10^7 dyn/cm^2 at 60 and 1.5 x 10^7 dyn/cm^2 in extreme old age.”

The unit “dyn” is not used now, “N: newton” is used.

1 N =10^5 dyn

No one knows how the power from the elasticity of the capsule changes into the pressure of the capsule onto the lens. However, as the unit of Young's Modulus of elasticity and that of the pressure are the same, the elasticity value should be converted into the quantity of pressure. Therefore, it is supposed that the elasticity value of the capsule can be converted into the pressure value onto the lens by the capsule.

Young's Modulus of elasticity is 3 x 10^7 dyn/cm^2 at the age of 60.

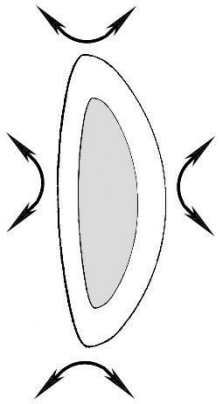
3 x 10^7 dyn/cm^2 = 3 x 10^2 N/cm^2 = 300 N/cm^2

This will be the maximum PRESSURE at that age.

Now we need to know another physical property of the capsule. The capsule has the ability warping outwards because of its elasticity. I quote from a book by Stewart Duke-Elder.

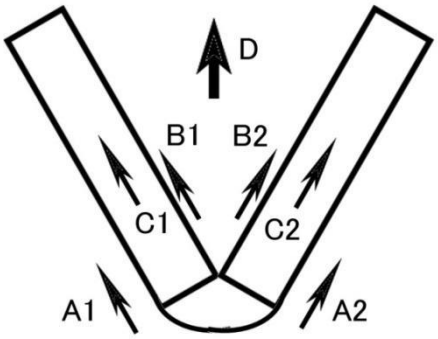
"It is very resistant to pathological and chemical influences, and is highly elastic, tending to roll outwards when cut, leaving a gaping wound.[14]" (Fig.4-8)

Fig.4-8 The capsule has the ability warping outwards.



To assume the actual PRESSURE put on the lens, we must think of the power of the capsule in two dimensions. First, we try to fold a fragment of 60-year-old eye's capsule to an angle 70°. (Fig.4-9) We assume the length of the fragment is about 300 μm. Because the capsule is stretched on the outside, pulling power works on the outside of the angle in the folded state. The pulling powers, named Power A1 and Power A2 respectively, pull the stretched portion of capsule. We think the value of the power will correspond to the value of 3×10^7 dyn/cm^2, because the fragment is stretched to a certain degree.

Fig.4-9 We try to fold a fragment of capsule to an angle 70°.



In the equatorial region of the lens, the power of accommodation by the capsule is put on the lens. However, when the lens relaxes as the zonule attached to the angle is pulling the capsule, the pressure on the lens equator will be nearly zero.

In accommodation, each Power A1 and Power A2 pulling on the outside is made by the power of Young's Modulus of elasticity, and each value of the power, or the pressure might be 300 N/cm^2. This is because the capsule is not being pulled by ciliary fibers at all in accommodation. It is thought that at that time, the capsule puts the maximum pressure on the cortex. In the most inside part of the folded capsule, since this part isn't stretched, each pulling powers named Power B1 and Power B2 will be always zero N/cm^2. I think that as there is a fulcrum on the top of the angle, the power starts at that point. Additionally, we assume that the power named Power C1 summed up Power A1 and Power B1 corresponds really to 1/2 of the number added Power A1 to

Power B1.

A1 = A2 = 300 N/cm^2, B1 = B2 = 0 N/cm^2

C1 = C2 = (A1 + B1) x 1/2 = (A2 + B2) x 1/2 = 150 N/cm^2

We regard Power C1 as the power in the anterior capsule, and Power C2 as the power in the posterior capsule. We assume that the angle of the axis of C1 is 30° against the longitudinal axis of the lens, and that the angle of the axis of C2 is 40° against the longitudinal axis. These numbers are rough, approximate values.

The pressure put onto the lens equator, named Power D is,

D = C1 x cos 30°+C2 x cos 40°≈ 150 x 0.87 +150 x 0.77 ≈ 246 N/cm^2

I think the elasticity of the capsule provokes a pressure of at most 246 N/cm^2 in the equator.

In the posterior pole, where the curve of the lens surface is acute next to the equator, the angle of the axis might be about 80° against the polar axis. In the same way, although the direction of the pressure is reversed, the pressure put onto the lens in the posterior pole, named power D-polar axis is,

D-polar axis = C1-p x cos 80°+C2-p x cos 80°≈ 150 x 0.17+150 x 0.17

≈ 51 N/cm^2

C1-p and C2-p in the posterior pole correspond to each C1 and C2 in the equator. At the posterior pole, as the capsule is pulled to the maximum extent by zonule in non-accommodation, the capsule puts the maximum pressure on the posterior pole in this state, not in accommodation. I think this pressure is not actually significant at all, and that it is really very small.

I think that the original or natural shape of the lens without the capsule is near to the shape in relaxation, and that the original or natural shape of the capsule without the cortex and the nucleus is near to the shape in accommodation. The lens without the capsule is, so to speak, a bare lens. Therefore, at a young age, in accommodation the bare lens will pushes the capsule on the equator, at the same time the capsule pushes the bare lens. The pressure in the lens is complicated.

<The value of real PRESSURE in the unit of mmHg>

We take into consideration the thickness of the capsule. P. Danysh et al. wrote as follows. “The equatorial region and the anterior pole in both accommodative and non-accommodative lenses are approximately five to ten times thicker than the posterior capsular pole.” “For instance, the adult human capsule measures between 25 μm and 30 μm at the anterior pole.[13]”

The thickness of the capsule is only about 30 μm, and from a microscopic view point, the capsule forms its shape into a gentle, rather than a sharp, curve in the equator. The stretched, outside part of the capsule drawn in Fig.4-9 is not real. The part of the capsule in the equator is stretched actually to a certain length of the segment. If the capsule is stretched any length, possibly the maximum power of Young's Modulus of elasticity might be at work. Therefore, the pulling power might be considerably strong; nevertheless, we attempt to estimate the small pressure. This is because something which weakens the power might work there. Therefore, I assume that the pressure made by the pulling power will truly be from 1/500 to 1/100 of the quantity of 246 N/cm^2 shown above.

The assumed real PRESSURE put on the lens equator is,

246 N/cm^2 x from 1/500 to 1/100

≈ from 0.49 to 2.46 N/cm^2

This is the conceivable value of the real PRESSURE.

To assume that the PRESSURE onto the lens cortex is 1/100 of the power provoked by the elasticity, it is 2.46 N/cm^2,

as 1 N ≈ 0.10197 kgf,

2.46 N/cm^2 ≈ 2.46 x 0.1 kgf/cm^2 ≈ 0.25 kgf/cm^2

As 1 kgf/cm^2 ≈ 98.0665 kPa,

≈ 0.25 kgf/cm^2 ≈ 0.25 x 98.0665 kPa ≈ 25 kPa
Converting the unit kPa to atm, as 100 kPa ≈ 1 atm,
≈ 25 kPa ≈ 0.25 atm, approximately.
As 1 atm ≈ 760 mmHg,
Converting 2.46 N/cm^2 into the unit of mmHg,
2.46 N/cm^2 ≈ 0.25 atm ≈ 0.25 x 760 mmHg ≈ 190 mmHg
This is the conceivable value of real PRESSURE in the unit of mmHg.

To assume that the pressure on the lens cortex is 1/500 of the power provoked by the elasticity, the PRESSURE is 0.49 N/cm^2. Converting 0.49 N/cm^2 into the unit of mmHg, it is 38 mmHg approximately.

It is conceivable that the capsule puts pressure of from 38 to 190 mmHg onto the cells on the equator.

The assumption of coefficients "from 1/100 to 1/500" are the hypotheses, and the value of the power has already been reduced by the angle of the direction of the power. The true number might be about 1/10 or 10/10. I think it is possible.

Even if the PRESSURE is 30 mmHg, the quantity will be enough to prevent the entrance of oxygen into the cell. In glaucoma, ganglion cells in the retina, or optic nerve cells, die through intraocular pressure slightly over 20 mm Hg. Of course, both the atmospheric pressure and the intraocular pressure also always press the cells on the equator other than the PRESSURE.

<Why does the oxygen partial pressure in the cell decrease?>

In the lens equator, if a cell is pressed by the capsule, the pressure difference appears between cells on the equator and surroundings. By the pressure difference, the pressure gradient arises. It is not an osmotic pressure gradient or a concentration gradient. We can regard the cell membrane as a semipermeable membrane. In the semi permeable membrane, by the pressure gradient, gas passes through the membrane from a space of high pressure to another space of low pressure. Molecules of oxygen and others pass the lipid bilayer of the cell membrane by the passive transport. In the cell on the equator, by the pressure gradient, oxygen cannot go into the cell of high pressure from surrounding cells and the aqueous humor. As a result, oxygen partial pressure in the cell decreases.

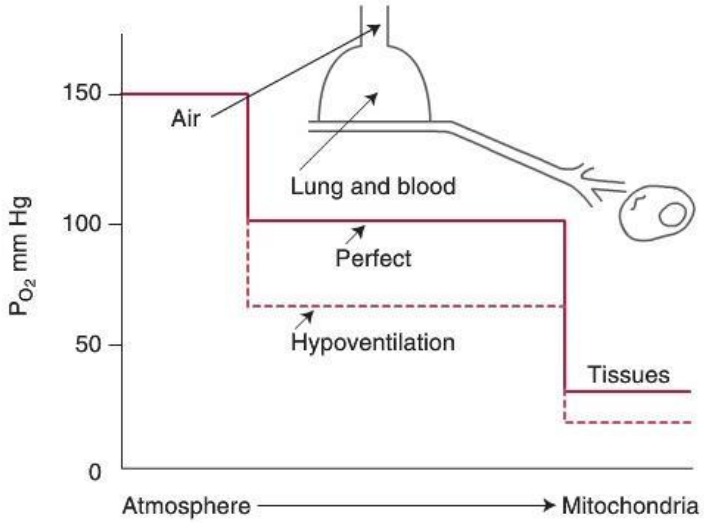
In this situation, oxygen will not be able to go into the cell of high pressure from surroundings. And at the same time, oxygen will be pushed out from the cell via high pressure.

Within the human body, intervertebral disks might have a similar environment, and an eyeball or a vascular system might also have a similar environment. In the eyeball, as intraocular pressure is about 18 mmHg, the pressure in the eyeball is about 18 mmHg higher than other tissue of the body.

Intervertebral disk: A layer of fibrocartilage between the bodies of adjacent vertebrae.[1]"

In the oxygen cascade, the oxygen partial pressure falls gradually depending on how the tissue is located in the periphery in the oxygen cascade. (Fig.4-10) It is generally explained that the reason for the reduction in oxygen partial pressure is the consumption of oxygen by cells and the tissue. Though, I think it cannot be explained sufficiently by that explanation.

Fig.4-10 The oxygen cascade [15]



I think, in cells on the equator, the concentration gradient also occurs at the same time. Although "pressure gradient" is "total pressure gradient" which contains "partial pressure," I think the total pressure and the partial pressure of a gas will work separately.

In the lungs, gas exchange is performed in the pulmonary membrane.
Pulmonary membrane: A membrane which supposedly includes components ranging from a membrane of alveolus to a red corpuscle.

I think in the pulmonary membrane, not only the concentration gradient, but also the pressure gradient of blood pressure occurs. We'll consider the following. In the lens equator, the pressure gradient made by the capsule surpasses the concentration gradient of oxygen. This is because in the lens equator, the pressure difference is rather large and the oxygen concentration difference is rather small. In the case of the lungs, the concentration gradient of oxygen surpasses the pressure gradient made by the blood pressure and the atmospheric pressure. This is because in the lungs, the oxygen concentration difference is rather large and the pressure difference between the blood pressure and the atmospheric pressure is rather small. In this case, of course, the "blood pressure" contains the atmospheric pressure. I think the pressure gradient might affect the fall of oxygen partial pressure.

And I think vascular endothelium might correspond to epithelial cells in the lens. And what happens in a corneal edema in glaucoma? Death of nerve cells of a retina in glaucoma? These are not our tasks.

In the equator, by the pressure gradient, the oxygen partial pressure in the cell decreases.

< "The unknown mechanism">

If the internal pressure of a cell on the equator increases, the oxygen partial pressure in the cell falls. Accordingly, oxygen in the cell will run short. Subsequently, the activity of mitochondria declines first. Because of this, the ATP required to maintain the activity of the cell is not supplied to the cell. Consequently, the cell membrane stops to function. The cell then accumulates Na(+) ions, and the cell gradually expands. Next, the cell organella stops to function and the cell itself dies. The destruction of the lens begins. This cell death is the beginning of a wedge-shaped cataract. This is the phenomenon David G. Cogan wrote about. And this is exactly the unknown mechanism we chased.

<The oxygen partial pressure in cells on the equator>

A human lens is floating in an aqueous humor in an aqueous chamber. The aqueous humor is located behind of the tissues in the oxygen cascade. Oxygen in the aqueous humor comes from a ciliary body, an iris, and partly from a vitreous body.

The aqueous humor depends on them for the supply of all nourish, including oxygen. The cells of a corneal endothelium die occasionally, through insufficient oxygen. It occurs often in a contact lens user. Those cells cannot survive through oxygen from the aqueous humor alone, and they depend on oxygen infiltrated from the surface of the cornea. Ying-Bo Shui said as follows, in rabbit eyes, "oxygen levels were highest near the surface of the pars plana of the ciliary body (21 mm Hg) and beneath middle of the iris (23 mm Hg). Near the pars plicata of the ciliary body, oxygen levels were only 16 mm Hg. As the aqueous humor moved beyond the midpoint of the iris, oxygen levels decreased to below 20 mm Hg.[16]"

There is a possibility that the oxygen partial pressure in the aqueous humor near the corneal endothelium is very low. It might be about 10 mm Hg. If so, the human cell might not be able to survive an oxygen partial pressure under about 10 mm Hg.

I think that the oxygen partial pressure in cells on the equator in non-accommodation is about 15 mm Hg or less, and that the pressure in accommodation might be below 1 mm Hg.

<Which cell is crushed on the equator?>

It is conceivable that the pressure resistance of an epithelial cell is originally not so high, and that the pressure resistance of a fiber cell is not so high on the equator. The epithelial cell moves under the capsule from the anterior polar region towards the equator by degrees, while it repeats cell divisions. It is conceivable that around the equator, the epithelial cell begins to transform into a fiber cell. During the transformation, the cell moves further inward towards the lens nucleus. On the course of transformation, while the cell loses its mitochondria, the fiber cell gains pressure resistance gradually.

It is conceivable that, at the beginning of the transformation, the fiber cell begins to gain pressure resistance. Even if it is low, it might be far higher than that of an epithelial cell. I assume that an epithelial cell starts to require a low quantity of ATP during the early stage of transformation, and that the cell membrane also starts to require the activity of Na(+)-K(+) ATPase less often. Finally, the fiber cell in the lens nucleus must require ATP less often, while oxygen and glucose will hardly be able to reach the lens nucleus.

It is conceivable that a cell which is crushed on the equator is an epithelial cell. This is because it must require a large quantity of ATP.

We can determine the cell crushed on the equator is the epithelial cell.

<People who do not suffer wedge-shaped cataracts>

From our clinical experience, people who suffer from wedge-shaped cataracts are in the minority. It is thought that in the major of people, the cells are not crushed at the equator in spite of the high PRESSURE. I think that in these people at the age of presbyopia, either epithelial cells begin, or have already transformed into fiber cells at the equator. Accordingly, as the cells do not require much ATP, they are not crushed at the equator. They do not suffer wedge-shaped cataracts.

4. The collapse process of the epithelial cell

Although an epithelial cell which has changed to a balloon cell does not break up yet, it is virtually dead. This dying epithelial cell attempts to change to a fiber cell. Next, the cells slowly begin to die. They begin autolysis. When it occurs, lysosomal enzymes are released into the cell itself.

Lysosome: One of the minute bodies seen with the electron microscope in many types of cells, containing various hydrolytic enzymes and normally involved in the process of localized intracellular digestion.[1]

Injured epithelial cells begin to be decomposed by lysosomal enzymes. Then those cells travel

the course, as if they have grown normally and go on their own way. After that, they become fragments of the cells, and they are decomposed completely at the end. Those decomposed substances develop into wedge-shaped opacity gradually. Cogan observes very correctly the collapse process of the epithelial cell, or the balloon cell.

5. Essential liquefaction

This is the 3rd of three types of histopathologic changes in cortical cataract which David G. Cogan listed. (Fig.4-11)

After the balloon cell formation, the next change begins. Cogan writes as follows.

"An alternative manifestation of corticolysis , less common than that associated with morgagnian globules , is essential liquefaction of the lens substance. Like the morgagnian globules, it also occurs in sharply circumscribed zones at intermediate depths of the cortex, but the zones are filled with granular debris and fascicles of disintegrating fibers rather than globules (Fig.6). It appears to be a rapid and direct process of corticolysis rather than a transition by way of morgagnian globules or balloon cells. This type of change may correspond to the "water clefts" seen with the biomicroscope in rapidly advancing cataracts.[4]"

Liquefaction: The conversion of a material into a liquid form.[1]

Fig.4-11 Essential liquefaction by Cogan[4]

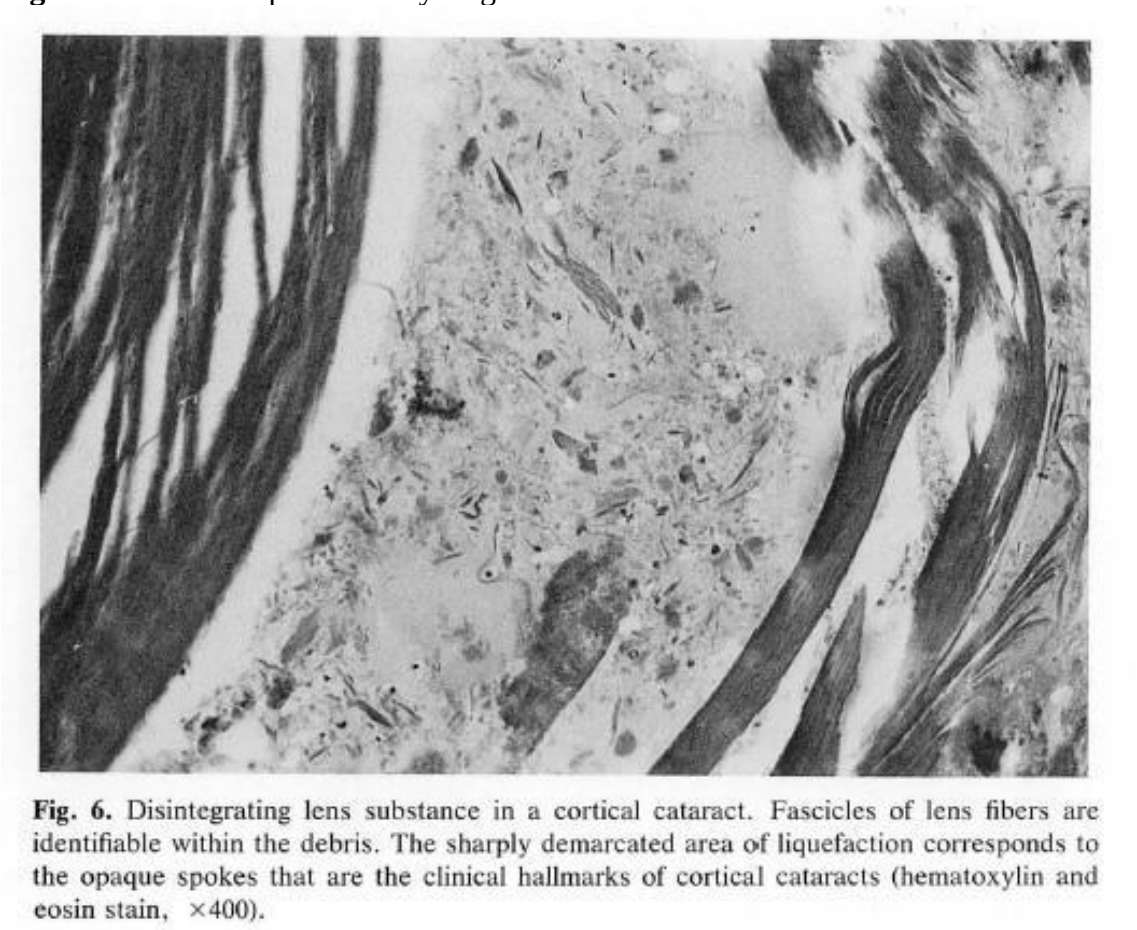


Fig. 6. Disintegrating lens substance in a cortical cataract. Fascicles of lens fibers are identifiable within the debris. The sharply demarcated area of liquefaction corresponds to the opaque spokes that are the clinical hallmarks of cortical cataracts (hematoxylin and eosin stain, ×400).

This is the 2nd stage of the lens collapse. Cogan describes the sight that lysosomal enzymes released from dying epithelial cells decompose the cells themselves. Cogan is not aware that the cause of corticolysis is the cell death by the PRESSURE. Though, he observes the advance process of cataract precisely. As he says, this essential liquefaction corresponds to the "water clefts." The essential liquefaction grows to the water cleft. The collapse of the lens develops from

the state of the balloon cell to the water cleft in which cells are decomposed by lysosomal enzymes.

6. Formation of eosinophilic globules (Morgagnian globules)

This is the 2nd of three types of histopathologic changes in cortical cataract which Cogan listed. He describes as follows. (Fig.4-12)

"Whereas balloon cells predominate in the subcapsular regions, the clusters of what are called morgagnian globules are found predominantly at intermediate depths of the cortex. The globules consist of eosinophilic discs without cell walls or other structures that are obvious by light microscopy (Fig.5). The cluster areas are bordered by lens fibers that appear, by contrast, remarkably normal. The globular configuration is probably an artifact of fixation. What appear microscopically as clear spaces between the globules undoubtedly result from shrinkage of the amorphous lens substance. This substance presumably corresponds in life to the opaque spokes of cortical cataracts.[4]"

Eosinophilic: Readily stainable with eosin.[1]

Fig.4-12 Formation of eosinophilic globules by Cogan[4]

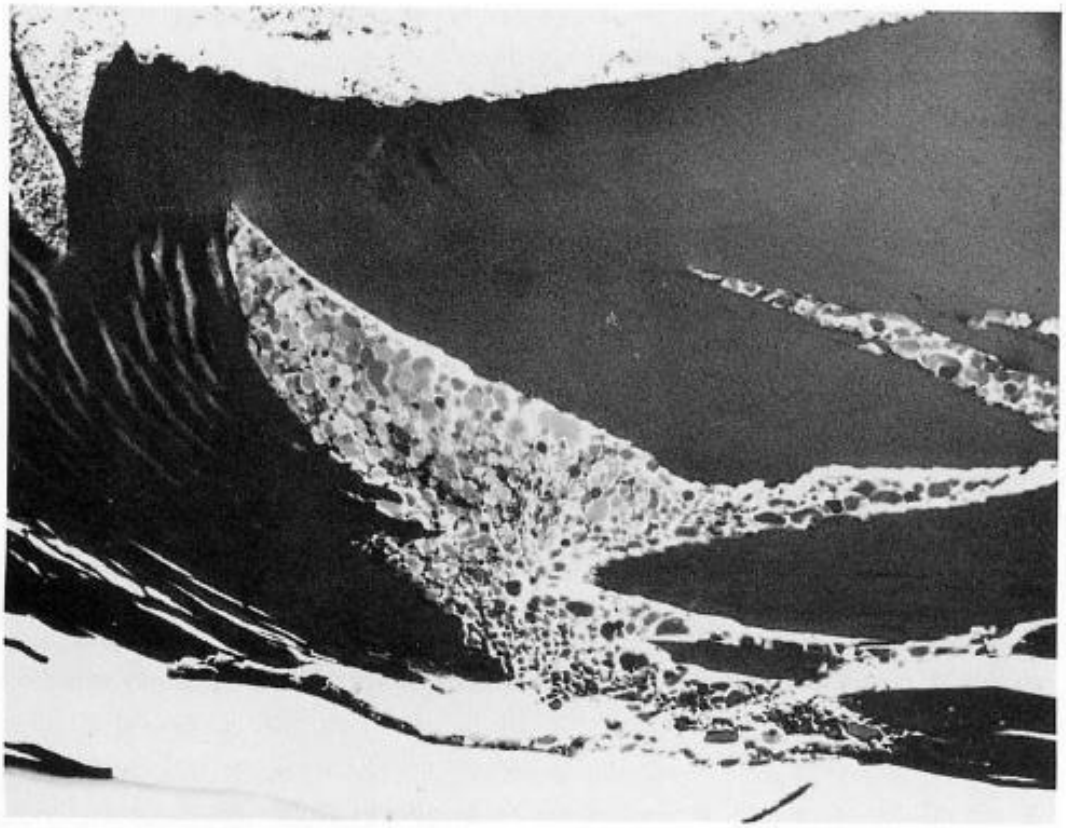


Fig. 5. Metamorphosed lens material in the form of morgagnian globules in a cortical cataract (hematoxylin and eosin stain, ×64).

Morgagnian globules and eosinophilic discs might be substances stuck together temporarily after the balloon cell has decomposed into minute substances via lysosomal enzymes.

This is the 3rd stage of the lens collapse. In this state, since the cell membrane and cell components have decomposed completely, they do not retain even the shape of the fragment of the cell.

<The water cleft>

After the 3rd stage, the early stage of the water cleft begins. This becomes larger by degrees. Afterwards the water cleft begins to give rise to new collapses of the fiber cells. Water clefts enlarge more; meanwhile, opaque substances begin to be made. Those opaque substances will be accumulated between the bundles of fiber cells, and then those substances gradually grow into larger wedge-shaped opacities. This is the wedge-shaped cataract.

The PRESSURE put on the lens equator travels in the wedge-shaped opacity from the equator to the anterior polar part of the cortex. The wedge-shaped opacity is a mass of opaque substances. The power of the opacity works on lens fibers destructively as Pressure[b].

<The collapse of the epithelial cell stops temporarily.>

The cells seem to continue to be crushed at the equator. However, it is not so. Ralph Michael et al. observed that phenomenon and wrote as follows.

"Panel of dark-field micrographs of old human donor lenses, illustrating the presence of mild (A and B) and advanced (D and E) cortical opacities along the entire circumference of the lens. Photographs taken before lens fixation. In D and E, the opacities extend as spokes into the pupillary space and will likely have affected the vision of the donors. The space between the outer limit of the opaqueness and the lens circumference is relatively transparent, becoming especially evident at higher magnifications of the boxed areas in (B) and (E) (C and F, respectively).[17]" (Fig.4-13)

Fig.4-13 The space between the outer limit of the opaqueness and the lens circumference by Ralph Michael et al.[17]

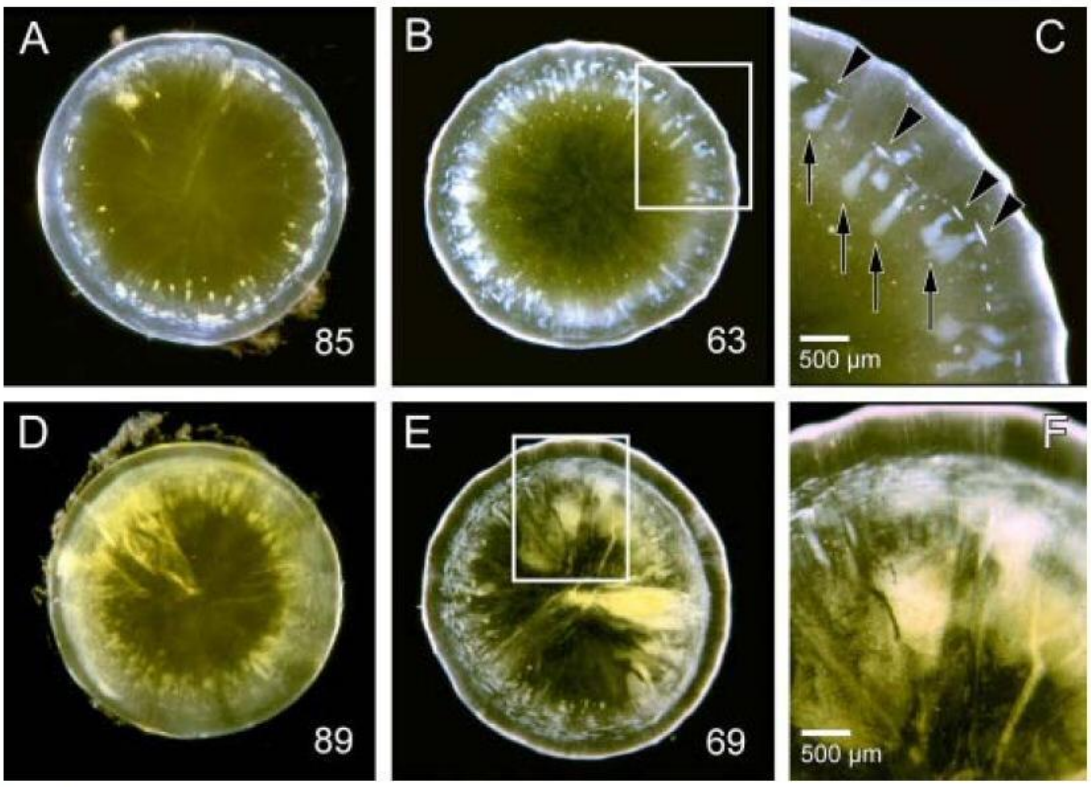


Fig. 2.

These phenomena are common changes in wedge-shaped cataracts. Cogan describes also these phenomena as follows, which I quoted before. "Some of these clusters of balloon cells may become displaced into the deeper cortex by the generation of normal overlying fibers."

Those phenomena indicate that epithelial cells cannot continue being destroyed in succession. After the water cleft has been formed, no hardened layer of fiber cells is under the equator. If fiber

cells under the epithelial cells have not made a layer of sufficient thickness, new collapses of the epithelial cells do not occur. In such circumstances, if the capsule puts pressure on the epithelial cells on the equator, the underlying water cleft cannot receive the pressure. The water cleft only diffuses the pressure deep into the lens. This is because the water cleft is soft, not hard. The collapse of the epithelial cell stops temporarily, until the next layer of hardened fiber cells grows. After a hardened layer of fiber cells has grown enough, the collapses of epithelial cells start again.

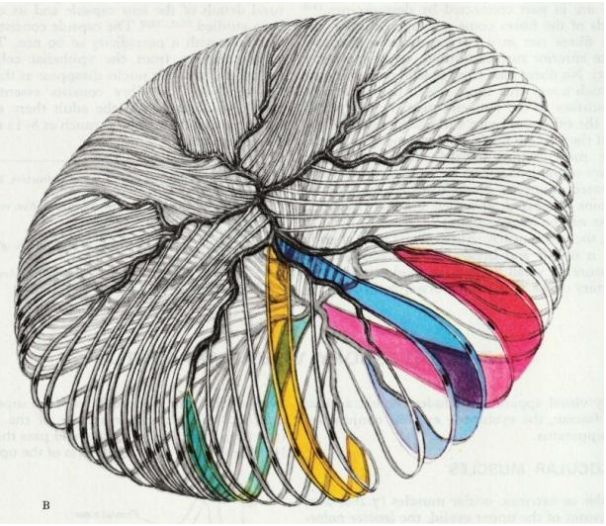
In these photographs, normal epithelial cells and normal fiber cells are not visible. Only insoluble proteins and insoluble aggregates in the water cleft are visible.

<The structure of the lens>

The water cleft in an advanced stage, is a wedge-shaped opacity. It begins to destroy surrounding cells by "Pressure[b]1" and "Pressure[b]2." What we named "Pressure[b]1", works as the power which slides a layer of fiber cells on the other layer. What we named "Pressure[b]2", works as the power which drives an apex of wedge-shaped opaque substances into an inter-layer space of fiber cell layers.

Pressure[b]1 and Pressure[b]2 work depending on a characteristic structure of the lens. (Fig.4-14) Gray's Anatomy describes this as follows, "it is clear that fibres pass from the apex of an arm of one suture to the angle between two arms at the opposite pole, as shown in the colored segments. Intermediate fibres show the same reciprocal behaviour, ending nearer to one pole, where they start further from the other, and so on.[18]"

Fig.4-14 A characteristic structure of the lens[18] from Gray's Anatomy



The lens fiber cells form a bundle, or a layer. If this bundle of hardened fiber cells moves due to the PRESSURE, the bundle causes Pressure[b]1. By this power the bundle slides on the neighboring layer of fiber cells. The bundle which moves is the wedge-shaped opacity.

The fiber cells connect to each other by interceller connection. (Fig.4-15) Edward Cotlier describes this as follows.

"The membranes of the fibers have side digitations that result in fiber interlocking[19]."

Fig.4-15 Interceller connection in the bundle by Edward Cotlier[19]

Fig. 10-7. Fibers in equatorial region of rabbit lens showing interdigitations among them. (Magnification ×3000.) (Courtesy Dr. George M. Wyhinny.)

When the wedge-shaped opacity moves, the slide of the wedge-shaped mass breaks the interceller connection, or the side digitation of the cells in the neighboring bundle.

<Lysosomal enzymes play a great role.>

When an epithelial cell is crushed, autolysis begins in the cell. As lysosomal enzymes are released into the cell, they begin to destroy their host cell. I think that after the host cell has been destroyed, the enzymes will not stop working.

On the equator, epithelial cells are crushed by the PRESSURE, and in the deep cortex, fiber cells are injured by Pressure[b]1. In both crushed epithelial cells and injured fiber cells, lysosomal enzymes are released into the cells. After the enzymes decomposed the cell, the enzymes which have got out of the cell will attack another fiber cell and destroy it. Lysosomal enzymes continue to destroy the fiber cells. In this way, lysosomal enzymes play a great role, and advance the wedge-shaped cataract.

<How long do lysosomal enzymes work?>

It is said that a lysosome contains about 70 sorts of enzymes. Among those enzymes, the most important enzymes which will develop wedge-shaped cataract are proteases.

In a human lens, the capsule forms a closed environment like a cell. This is a closed space. (Fig.4-16) Edward Cotlier describes. “In the normal lens the membrane of the lens fibers and the lens capsule do not allow the passage of protein molecules from the lens to the aqueous humor.[19]”

Fig.4-16 A closed environment in the capsule by Edward Cotlier[19]

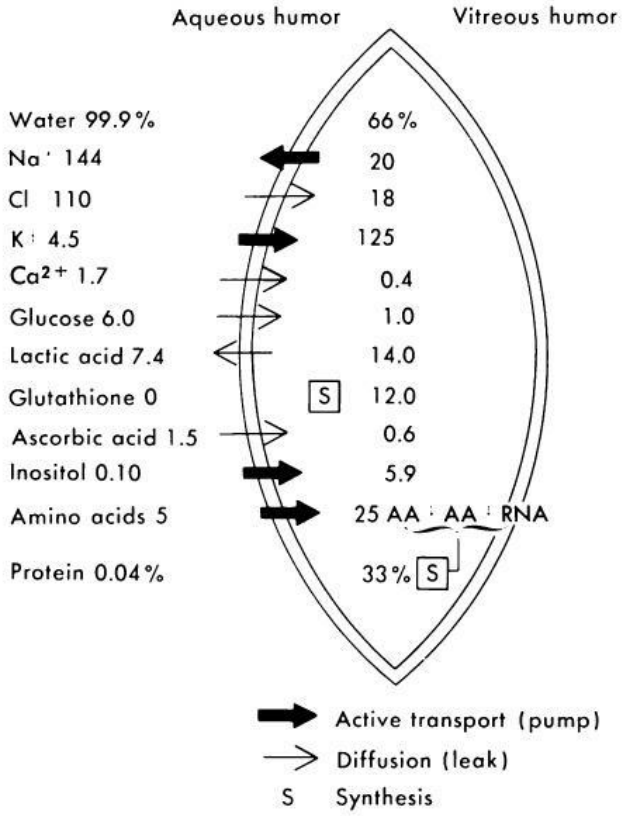


Fig. 10-8. Chemical composition of aqueous humor and lens. Water and protein are expressed in percent of lens weight. Na^+, Cl^-, K^+, and Ca^{2+} ions in μEq/ml lens water. Other compounds are expressed in μmol/g of lens weight or μmol/ml of aqueous humor. *AA*, Amino acids; *RNA*, ribonucleic acid.

Because lysosomal enzymes are proteins, they are not carried out of the lens, and in this enclosed special space, neither the blood stream nor the lymph flow exists. Therefore, the enzymes are not carried out of the space. The enzymes remain in the lens.

The half-life of these enzymes is known to be about 10 to 30 hours.[20] It is conceivable that after the enzymes have been released into the cell from the lysosomes, they might stay in the cell for about 10 to 30 hours before the enzymes get out of the host cell. If so, the enzymes cannot attack other cells.

Osato Miyawaki et al. wrote about the half-life of enzymes. Those enzymes were glucoamylase and β-galactosidase. "Half-life of enzyme increased by ten-to thousand-fold with coexistence of substrate.[21]" "Proteins are known to be marginally stable in an aqueous environment.[21]" Substrate: A substance upon which an enzyme acts.[1]

They said that the coexistence of substrate prolonged the half-life of enzymes to from 10 to 1,000 times. In a human lens, after lysosomal enzymes destroyed some epithelial cells, substances which the enzymes may attack remain plentifully. Therefore, there is the possibility that the life spans of those enzymes may drastically elongate and, if the catabolic enzymes are decomposed only by other catabolic enzymes, it is assumed that the life spans of those enzymes are prolonged further. In the lens, the probability that the enzymes meet one another is very small because of the plentiful substrates there. For this reason, the enzymes in the lens will hardly decompose. Accordingly, the life spans of enzymes will be extremely prolonged. It might be as much as 5 or 10 years.

Recurrent crush of the cells on the equator by the pressure and repeated attacks on the cells in the lens by the enzymes advance the destruction of the lens. As lysosomes in the fiber cell will

continue decreasing depending on growth of the cell, it is assumed that new enzymes in the lens are supplied mainly from the collapse of epithelial cells.

In this way, the collapse of cells begins to occur all over the lens. Moreover, since other biochemical changes increase, the opaqueness of the cataract falls into great confusion.

7. The progression of wedge-shaped cataracts

Insoluble proteins and insoluble aggregates will adhere to the surface of the cell membrane around the water cleft. I think that as adhered insoluble substances stiffen the membrane of the fiber cell, the cell becomes more easily crushed by the PRESSURE. The insoluble substances adhere not only to the cell around the water cleft, but also to cells further from the equator.

Edward Cotlier writes as follows. "The spaces between the lens fibers, the extracellular spaces of the lens, are very small, accounting for only about 5% of the lens volume.[19]" It is conceivable that those insoluble substances adhere through these spaces to the surfaces of far cells.

<Opaque lines>

In the lens cortex away from the equator, very fine opaque lines of a large number come out in parallel, crossing the wedge-shaped opacity. It is conceivable that these lines of opaque substances are made from cells crushed by Pressure[b]1. Pressure[b]1 makes gaps in the layer of fiber cells. Consequently, the interceller connection of the neighboring layer breaks and the cell membrane is injured. I think, as if this power by the lump of wedge-shaped opacity would have rolled the crossing fiber cells in neighboring bundles, this power crushes the fiber cells and then makes opaque parallel lines.

<Wedge-shaped opacity grows toward the pole.>

When the wedge-shaped opacity has already developed, it is conceivable that besides Pressure[b]1, Pressure[b]2 also works. The latter is the power which drives the apex of the wedge-shaped opaque substance into an inter-layer space of bundles. This power, at the apex, expands the space between the layers. Consequently, as the opaque substances can pass easily through this space, the wedge-shaped opacity will grow rapidly toward the pole.

When the wedge-shaped opacity has increased to a certain degree, the PRESSURE spreads in every direction over the lens. This is because hardened opacity which receives the pressure has been made everywhere. As a result, the various ways of destroying the lens complicate the cataract. Depending on the progression of the cataract, the structure of the whole lens becomes weak. The lens will become more easily destroyed.

8. Speckled opaqueness

When wedge-shaped opacity has developed to a certain degree, speckled opaqueness comes out near the anterior pole of the lens cortex. Like the wedge-shaped opacity, it makes a plane parallel to the lens surface. When wedge-shaped opacity has developed to a certain degree, the epithelial cells in other than the equator are sandwiched between the capsule and the opacity. Those epithelial cells will be crushed by this sandwiching power. This power is Pressure [d].

Moses describes, "In the eye during accommodation," and continues as follows. "3. The anterior surface of the lens becomes more convex. The posterior surface increases its curvature slightly. 4. Since the posterior pole remains fixed and the anterior pole moves forward, the thickness of the lens at the center increases.[6]"

In accommodation, although the anterior surface of the lens more expands than the posterior surface, the anterior capsule margin of expansion is less than the posterior margin. The diagram,

in Fig.4-17 by Moses, shows the shape of the capsule. Accordingly, it is assumed that in accommodation, the anterior capsule puts stronger pressure on lens epithelial cells than the posterior capsule does on fiber cells. But in fact, it is thought that as the capsule presses the lens equator, the anterior polar portion of the lens cortex is pushed onto the anterior capsule. Pressure [d] is caused by Pressure[a] and Pressure[b]. Epithelial cells are sandwiched in that location.

Fig.4-17 The shape of the capsule by Robert A. Moses[6]

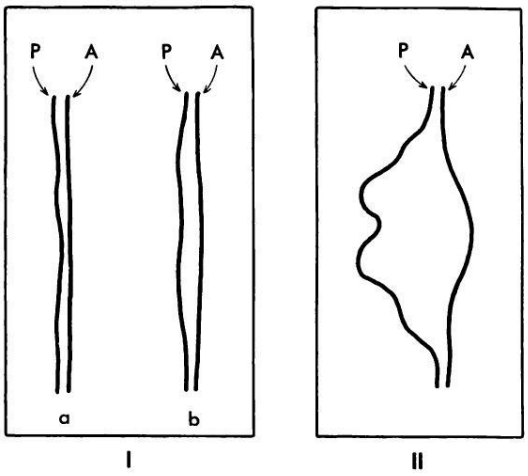


Fig. 11-7. I, Normal state of capsule at rest. Posterior capsule (*P*) is more mobile than anterior capsule (*A*) and sometimes floats forward almost to touch anterior capsule (*a*) and at other times floats backward (*b*). **II,** Capsule under influence of eserine. It has now become very lax. (Modified from Graves.)

9. The Breakdown of the human lens

The diagram of the prevalence of cataracts shows a rapid increase in cataracts from the age of about 50. (Fig.4-18) This is an unexpected incident for the plan of the human eye. For the plan, it was not anticipated that the UNREASONABLE POWER is used at that age. The occurrence of the collapse of fiber cells was not anticipated. This suggests that the planned life span of the human eye might be about 50 years.

Fig.4-18 The prevalence of cataracts by John Harding[3]

Figure 3.3 Prevalence of cataract. A. Framingham: Lens opacity with VA 6/9 or worse (Leibowitz *et al.*, 1980); B. USA: Lens opacity causing VA 6/7.5 or worse (Leske and Sperduto, 1983); C. Punjab: Cataract with VA 6/18 or worse or aphakia (Chatterjee *et al.*, 1982); D. England: Definition as A. (Gibson *et al.*, 1985); E. New Zealand: Definitions as A (Martinez *et al.*, 1982); F. Tibet. Cataract with VA 6/12 or worse (Hu *et al.*, 1989).

It is conceivable that after the opaqueness has advanced to near the anterior polar area of the cortex, lysosomal enzymes come to play a main role in the crushing the cell. The PRESSURE also continues working all over the lens until the later stage of cataracts. In this circumstance, as the capsule continues shaking the lens, cataract advances more steadily because of lysosomal enzymes. Then the wedge-shaped cataract develops gradually into a mature cataract : a "cataract in which the lens is completely opaque,[1]" then into a hypermature cataract : a "cataract in which the contents have become either solid and shrunken or soft and liquid,[1]" further into a morgagnian cataract : a "cataract with a fluid cortex and a hard nucleus[1]" and ultimately to phacolysis : "dissolution of the lens.[1]" It is the end form of age-related cataracts. The phacolysis causes phacolytic glaucoma: "glaucoma secondary to leakage of lens protein into the aqueous from a hypermature cataract.[1]" This is an extra.

10. Subcapsular cataract is also caused by the PRESSURE.

Cogan writes as follows. "Underlying the pathogenesis of posterior cortical cataracts is the antecedent migration of epithelial cells beneath the posterior capsule from the equator toward the posterior pole.[4]" The cells in subcapsular cataracts are the very cells in wedge-shaped cataracts.

It is conceivable that in accommodation, a lifting power, or Pressure [c] works at the posterior polar region. The posterior capsule will be peeled off from the lens cortex and into this space, separated epithelial cells from the equator migrate.

11. Miotics-induced cataract

This is a cataract caused by the application of miotics for a long period of time. "Miotics" are eye lotions which contract the pupil. The opaqueness of this cataract comes out under the anterior capsule as speckles.

In miotics-induced cataracts, the PRESSURE works for a long time continuously on the equator. It will pass through the cortex to the anterior pole, and presses on epithelial cells in the

anterior polar region. This Pressure [d] as repulsion for Pressure[a] and Pressure[b] crushes epithelial cells in the region.

12. Christmas tree cataracts

In this rare cataract, brilliances like Christmas tree lights emerge in the lens nucleus. It is conceivable that the brilliance of this cataract is cholesterol in the cracks of the lens nucleus. I consider that the cracks are caused by the PRESSURE, and that the power is so strong as to crack a considerably hardened nucleus.

Discussion

I solved the riddles of cataracts. The cause of the wedge-shaped cataract is the unreasonable power of accommodation. Therefore, everyone can prevent wedge-shaped cataracts and can stop their progression.

MEASURES

1. How should we avoid using the UNREASONABLE POWER?

I call the age over 41, "the age of presbyopia."

From the age of presbyopia, in order not to use the UNREASONABLE POWER, we must use reading glasses with "lenses of sufficient strength." "Lenses of sufficient strength" compensate for a short degree of the power of accommodation.

2. Reading glasses of sufficiently strong power

Almost all eye doctors probably prescribe eyeglasses using the "lens change method." Using this method, a doctor asks a patient as follows. "With which lens can you see better, this one or before?" In this way, the doctor decides the lens power. This method is not suitable for preventing wedge-shaped cataracts, however. When a patient is fitted with glasses using this method, she might use close to the maximum power of accommodation during the test. Accordingly, her glasses will run short of degree.

At the age of 40, in theory, a person should not use the accommodation power of 3.3 D. Considering that the danger of cell being crushed increases with age due to the high PRESSURE, we need to reduce the power of accommodation as early as possible. For this purpose, everybody should wear reading glasses from the early 40's onwards. In this way, we can put an end to the UNREASONABLE POWER.

However, at the age of 40, as remnants of POWER work a little, the eye feels that reading glasses of 3.0 D are too strong. It is the same over the age 40, while an eye retains some power of accommodation. If eyeglasses are fitted using the "lens change method," reading glasses which run several degrees short will be made.

Sufficiently strong power for reading glasses is the degree which makes up for the shortage in diopters at each age. This shortage is the difference between the power which an eye uses to look at nearby objects and the power which is normally usable in accommodation at each age. To make these spectacles, they must be prescribed using a method I call the "adding fixed degree method". This is the only way to prevent the UNREASONABLE POWER.

I will explain the "adding fixed degree method." In this method, we add the fixed amount of degrees at each age to the fitted degrees of a patient's glasses to see distant objects. The fixed amount is 1.0 D at the age of 42, 1.5 at the age of 45, 1.75, at the age of 47, 2.0 at the age of 50, being increased 0.25 D for every 2.5 years of age after that, finally reaching the fixed amount of 3.0 D at the age of 60. Over the age 60, the fixed amount is 3.0 D for the rest of the patient's lifetime. Moses says as follows.

"Further loss of the accommodative power with recession of the near point, continues unabated until about the age of 60 years, by which time all the accommodation has been lost.[6]"

The 3.0 D of a lens about 12 mm in front of an eye is equivalent to 3.25 D for the eye itself. The focal length of 3.25 D is about 30 cm. Lenses of eyeglasses are made using steps of 0.25 D. If reading glasses of a higher diopter number than 3.0 D are used after the age 60, the eye will only be able to see nearer than 30 cm by those glasses.

If everyone wears reading glasses of sufficiently strong power after the age of about 42, it is possible to prevent the destruction of the human lens completely. Even if a person wears glasses later than that, he can stop the progression of cataracts on the condition that the destruction of the lens is not too far advanced. Additionally, even if the cataract has advanced significantly, reading glasses of sufficiently strong power will be able to delay the progression of a wedge-shaped cataract.

However, to people, it is difficult to understand what presbyopia is, and what the reading glasses are. Many people do not know what they use reading glasses for. They say, "I can read a newspaper without glasses." Eye doctors are lacking in effort.

3. Spectacles with progressive multifocal lenses

In a vertical writing culture, spectacles with progressive multifocal lenses cannot take the place of reading glasses of sufficiently strong power. In a progressive multifocal lens, the part used to see nearby objects is in the lowest position. (Fig.5-1, 5-2) The part for near vision has some spread in the horizontal direction. However, that part has very narrow spread in the vertical direction. Therefore, the spectacles are useful in a horizontal writing culture, but in a vertical writing culture, a person cannot read vertical sentences. He will read vertical sentences through the part to see distant objects. This is a very important matter. No one is aware of it, however, because Europe and America are in the horizontal writing culture. Even in the horizontal writing culture, progressive multifocal glasses are not enough for preventing the unreasonable power of accommodation. A person in the horizontal writing culture might look at a nearby object through the part to see distant objects. Many people do not know that the upper part of the progressive multifocal lens is only for seeing distant objects. They might think they can look at everything, near or far, through the center of the progressive multifocal lens because they wear "multifocal glasses."

Fig.5-1 A progressive multifocal lens (a front view)

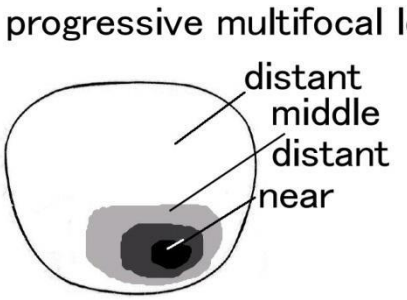
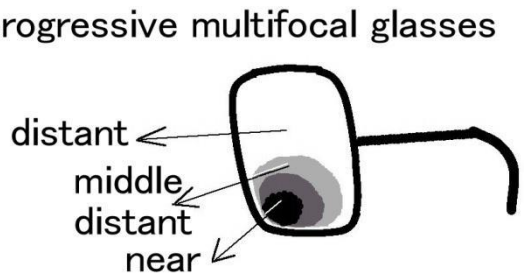


Fig.5-2 A progressive multifocal lens (a side view)



And reading glasses are used not only to read sentences, but also to look at everything nearby.

Everyone must look at not only sentences, but also every nearby object with reading glasses. Then, we should stop using the label “reading glasses,” and we should call those glasses “close-at-hand glasses,” for example.

THE NEAR FUTURE

Edward Cotlier writes about cataracts in “ADLER’S Physiology of the eye.” “Biochemical abnormalities may herald morphologic changes of the lens.[19]” Everybody who studies cataracts thinks like this; however, it is not true. In a wedge-shaped cataract, morphologic changes begin first, and then biochemical abnormalities follow. Therefore, no one could discover the cause of cataracts, even though they investigated all biochemical changes. The excellent researcher John Harding knows all about biochemical changes in cataracts. Harding writes in his book “CATARACT Biochemistry Epidemiology and Pharmacology (1991),” as follows.

“In the last chapter I deal with the prevention of cataract and its delay by anticataract agents. There have been enormous advances in this area in the past few years and there is the promise of an effective therapeutic treatment soon.[3]”

It is very regrettable.

Wedge-shaped cataract is the destruction of the lens caused by the PRESSURE. Before cataract occurs, the “excessive accommodation” develops myopia, and it gives rise to the “distorted lens.”

The planned life span of a human lens will be about 50 years. The role of the human lens as an optical lens ends at that time. But the human life span is getting longer, and it continues to do so. In near future, the average human life span might reach 100 years. Like the human life span, we must extend the life span of the human lens.

As we can prevent cataracts by using reading glasses, which are easy to use, we can reduce the number of cataract surgeries. In an ophthalmologist’s office, this prevention will be sensed within three years as it stops the cataract progression in patients’ eyes. In a large institution of ophthalmology, this will be recognized within three years as a decrease in the number of cataract surgeries. However, they will never do so. This is because they do not want to lose the large profits from cataract surgeries. But we should not forget their big profits are big losses of people.

So many surgeons of ophthalmology are operating cataracts every day in the world. They never think about the cause of cataracts. We are in the Dark Ages today.

Now, we can estimate the rough number of cataract surgeries all over the world. We will name the total number of cataract surgeries operated in the world “TOUT.” I think the types of cataract surgeries are as Fig.5-3. I estimate each percentage of surgeries in TOUT. About 60% are wedge-shaped cataracts, about 35% are nuclear cataracts and about 5% are subcapsular cataracts.

Fig.5-3 Itemized cataract surgeries

I suspect as follows.

“Wedge-shaped cataracts” / TOUT will now be 60 %. But I think that “true wedge-shaped cataracts” / TOUT are about 30 %. The rest of the “wedge-shaped cataracts” are really the visual acuity loss due to the distorted lens. Accordingly, this corresponds to about 30 % in TOUT.

And, “nuclear cataracts” / TOUT are 35 %. As with the wedge-shaped cataract, I think that “true nuclear cataracts” / TOUT are 5 %. The rest of “nuclear cataracts” will be the visual acuity loss by the distorted lens. I think this corresponds to 30 % in TOUT.

Therefore, the true items of cataract surgeries will be as Fig.5-4.

.

Fig.5-4 Corrected itemized cataract surgeries

We can prevent cataract and the distorted lens by using reading glasses of sufficiently strong power. Using reading glasses is an easy way to practice. The 30 % of TOUT operated as wedge-shaped cataract, and another 30 % of TOUT operated as nuclear cataract will go away. The total ratio of those useless surgeries is at most 60 % of TOUT. Of course, most of the original surgeries for wedge-shaped cataract become unnecessary by using reading glasses of sufficiently strong power. That ratio in TOUT is at most 30 %. The surgeries for wedge-shaped cataracts and the surgeries for the visual acuity loss due to a distorted lens will become unnecessary. They come to at most 90 % of TOUT in total.

And we might be able to prevent nuclear cataracts. It is known that AGE is one of the causes of nuclear cataracts. If we avoid a large amount of food which contains AGE or makes AGE, we will be able to reduce nuclear cataracts. Those foods are heavily roasted meat, fried potatoes and the like, fructose or fruits, sugar and baked sugar, carbohydrate-rich foods and so on.

We, or you and I, can decrease the number of cataract surgeries, by using reading glasses of sufficiently strong power. We can decrease the number of all present operations by at most 90%. Enormous numbers of cataract surgeries which are primarily needless are operated every day all over the world. I think the greatest enemy of mankind is the ignorance. We must know the truth.

In near future, the average life span of the human lens must become 100 years.

Cataracts were the great cold case.

Materials and Methods

Materials: Literature of Predecessors. Methods: The author’s thinking.

References

1) *DORLAND'S ILLUSTRATED MEDICAL Dictionary* (W.B. SAUNDERS, ed. 25, 1974).
2) D. Paton, J. A. Craig, Cataract, *CLINICALSYMPOSIA **19*** (CIBA Pharmaceutical Company, 1974).
3) J. Harding, *CATARACT Biochemistry Epidemiology and Pharmacology* (Chapman & Hall, 1991).
4) D. G. Cogan, Pathology of Age-Related Cataracts, *Clinical ophthalmology Vol 1* (Lippincott, 1990).
5) J. Parr, *Introduction to Ophthalmology* (Oxford University Press, 1978).
6) R. A. Moses, Accommodation, *ADLER'S Physiology of the eye* (Mosby, 1987).
7) R. S. Snell, M. A. Lemp, *Clinical Anatomy of the Eye* (Blackwell Scientific Publications, 1989).
8) KR Heys, Massive Increase in the Stiffness of the Human Lens Nucleus with Age: The Basis for Presbyopia? *Mol. Vis.* **10**, 956-963. (2004). (on the net)
9) E.A. Hermans, M. Dubbelman, G.L.v.a.d. Heijde, R.M. Heethaar, Change in the accommodative force on the lens of the human eye with age. *Vision Research* **48**, 119-126. (2008). (on the net)
10) R. F. Fisher, Elastic Constants of the Human Lens Capsule. *J. Physiol.* **201**, 1-19. (1969). (on the net)
11) S. Bassnett, D. C. Beebe, Coincident Loss of Mitochondria and Nuclei During Lens Fiber Cell Differentiation. *Developmental Dynamics* **194**, 85-93 (1992). (on the net)
12) J. D. Rawn, *Biochemistry* (Neil Patterson Publishers, 1989)
13) B. P. Danysh, M. K. Duncan, The Lens Capsule. *Exp. Eye Res,* **88**, 151‑164 (2009). (on the net)
14) Sir S. Duke-Elder, *The Anatomy of the Visual System, System of Opthalmology V. II*, (Henry Kimpton, 1967).
15) Wikipedia - pEx, Oxygen Cascade - pEx, http://pex.referata.com/wiki/Oxygen_Cascade (last visited Sep 21, 2017).
16) Ying-Bo Shui, Oxygen Distribution in the Rabbit Eye and Oxygen Consumption by the Lens. *Investigative Ophthalmology & Visual Science* **47,** 1571-1580. doi:10.1167/iovs.05-1475 (2006). (on the net)
17) R. Michael, R. I. Barraquer, B. Willekens, J. v. Marle, G. F.J.M. Vrensend, Morphology of age-related cuneiform cortical cataracts: The case for mechanical stress. *Vision Research* **48**, 626–634 (2008). (on the net)
18) R. Warwick, P. L. Williams, *Gray's Anatomy* (Churchill Livingstone, ed. 35, 1973).
19) E. Cotlier, The lens, *ADLER'S Physiology of the eye* (Mosby, 1987).
20) R. T. Dean, *Lysosomes* (Tuttle, 1977).
21) O. Miyawaki, T. Kanazawa, C. Maruyama, M, Dozen. Static and dynamic half-life and lifetime molecular turnover of enzymes. *Journal of Bioscience and Bioengineering* **123**, 28-32 (2017). (on the net)

Acknowledgements

Author Contributions: Naomi Okuyama designed and wrote the paper in Japanese in September 2017. N. Okuyama searched his bookshelf and the net for literature. Hajime Nunokawa, Superintendent of Education of Ohishida Town Office, Japan, advised N. Okuyama about Young's modulus of elasticity. N. Okuyama translated the paper from Japanese into English. Aaron Kempf belonging to Office Nine, Yamagata-city Japan, proofread the paper about English grammar in January 2018.

Competing interests: The author declares no competing financial interests.