differently according as they alter the tension of the liquid freely exposed to the air, or the tension of the liquid in contact with the glass, which is not of the same value.

With respect to Proposition III. there is no difficulty. A liquid of considerable contractile force, such as pure water, produces no separation of salt in a solution of less contractile force. This explains a number of cases described in a note by one of us submitted to the Society in July last*, in which solutions exposed for hours together to heavy rain did not crystallize, unless the rain brought down a speck of soot or some unclean body that lowered the surface-tension of the solution. Indeed we know of no liquid of superior tensile force to that of the solution, and not acting chemically upon it, that has any influence in producing crystallization.

Proposition IV. also agrees with the phenomena. A glass rod or other solid, more or less smeared with a film of a liquid of low tension, when brought into contact with the solution determines crystallization by lowering the surface-tension. Such, then, is the function of a nucleus with respect to supersaturated saline solutions. If the solid be made chemically clean, it may be plunged into the solution without altering its tension, and hence there is no separation of salt. And here it may be remarked that such a case is possible that a crystal of the salt itself may be brought into contact with the solution without disturbing its tension, and hence be inactive. It has never been pretended that a crystal of the salt is not a good nucleus for a supersaturated solution of its own kind; all that has been stated by one of us is that, under special conditions, such a crystal may be lowered into the solution without acting as a nucleus.

III. "Remarks on the Sense of Sight in Birds, accompanied by a description of the Eye, and particularly of the Ciliary Muscle, in three species of the Order *Rapaces*." By Robert James Lee, M.A., M.D. Communicated by Robert Lee, M.D., F.R.S. Received April 11, 1872.

It is proposed in this communication to describe certain peculiarities in the eye of the bird as compared with the eyes of other vertebrata; and further to examine to what extent those peculiarities enable us to explain the remarkable powers of sight with which all species of birds are more or less highly endowed.

Those who study the habits and modes of existence of the lower animals, find great interest in applying to various phenomena connected with them the results of anatomical investigation, and in endeavouring to discover such causes, or means adequate to produce such effects, as to render the supposition of the existence of an indefinite property like instinct very frequently unnecessary.

This method it is my desire to apply in the explanation of those high

* *Suprà*, p. 41.

and distant flights which are performed by certain species of birds in search of food or in their migrations to different localities.

For us it is difficult to form a clear conception of the power of sight possessed by birds if we only use our own faculties in this respect as the standard of comparison; by which I mean to imply that the mind must be prepared for the consideration of the phenomena referred to by observing in detail numerous important differences in the structure of the eye, which combine to facilitate a conception of ideas otherwise beyond the reasonable limits to which even imagination might extend.

This field of inquiry will long engage the attention of the naturalist and anatomist; indeed it may be said to be inexhaustible; and I feel considerable hesitation in offering a contribution insignificantly small to the elucidation of a subject of such magnitude.

We may acquire some idea of the sight of the bird by comparing the dimensions of the eye with those of the brain or the optic lobes; and by arranging the measurements thus obtained, and referring them to some fixed standard, we may estimate the relative and individual powers of vision enjoyed by different species. In illustration of this we have an instance, in the case of one of the birds which I propose to describe minutely in this communication, in which the eye is actually considerably larger than in the human species; and we have a still more striking example, considering the size of the bird, in the *Goura coronata*.

Again, if we regard the eye as an optical instrument, we may estimate its efficiency by examining the internal structures on which the formation and perception of the image depend,—such as the size and coefficient of refraction of the lens, the extent and character of the retina, and particularly those differences of minute structures which have relation to susceptibility to light, by which the night-flying birds are distinguished from the day-flyers. Nor does the inquiry into the effects of domestication upon the sight appear less interesting.

It is only to point out the various ways in which we may deal with this subject that I have mentioned these different lines of research, and in order that it may be understood that I have not overlooked their importance. It is to one particular property of the eye that my own observations have been chiefly directed, namely, the power of accommodation for distance; and I shall endeavour to show that in birds great range of vision depends upon the development and character of the ciliary muscle, to which all are agreed that the power of adjustment is to be attributed.

It is chiefly, then, a comparison of the ciliary muscle in different birds to which I invite attention, assuming the perfection of the sight to depend on this power of accommodation, and that again on the character of the muscle. Let me first mention the general opinion entertained by those who are best acquainted with the habits of that class of birds which astonish us by the rapidity and duration of their flights, namely the pigeons, in regard to the means by which they accomplish them. In his

interesting work on this subject Mr. Tegetmeier gives his reasons for concluding that "Homing," as it is termed in the Antwerp pigeon, is not the result of "instinct," but of "observation." These pigeons require to be trained stage by stage, or they are certain to be lost. The best of them refuse to fly in a fog or in the dark. They crave in new localities some known landmark; and hence their gradually increasing gyrations, until having descried some familiar object, they recollect their route and fly straight ahead. The objection that no pigeon can possibly see for two hundred miles ahead is met by the details of aëronautic experience. Mr. Glaisher, half a mile aloft in air, could embrace in his "bird's-eye view" the course of the Thames from the Nore to Richmond; and Mr. Wheelwright, though puzzled to account for the flying pigeons "homing" across seas (as from London to Antwerp), which can offer no landmark, is disposed to attribute their power of doing so to their habit of soaring round, circling, and beating about until, sooner or later, they can descry their familiar guide-posts.

My own observations entirely support Mr. Tegetmeier's conclusions. This part of my subject is one of general interest, and I trust that I shall be pardoned for attempting to alleviate the tediousness of anatomical details by this digression.

It must clearly be understood that perfection of sight for very near objects is as important as very extensive range, and that the chief function of the ciliary muscle is to adjust the sight for the former rather than for the latter. When the eye is at rest (that is to say, when the muscle is relaxed) vision of very distant objects is permitted; and it is when the distance is diminished to a very few inches, and in small species of birds to considerably less than an inch, that the action of the muscle is exerted.

The exact functions performed by the ciliary muscle in all those vertebrata in which it exists are still undecided; but it is not difficult to reconcile the accounts which have been given by different anatomists of its structure, if we are aware of the fact that the muscle does not possess the same characters in all classes of animals; indeed that it is not precisely the same in those that are very nearly allied, so that it is important, particularly in the case of birds, as will be seen, to mention the species under consideration.

It may be stated generally that in birds it is developed in a remarkable degree; in fish it is entirely wanting; in the mammalia it varies directly in proportion to the powers of sight possessed by the species, except in the feline class and in those animals which enjoy the power of nocturnal vision, and in which the ciliary muscle is peculiarly large and differently developed from the same structure in other mammals.

The three specimens which are to be described belong to the Eagle Owl, the Egyptian Vulture, and the Buzzard. They were brought from Egypt by a gentleman who shot the birds himself, and removed the eyes while in the fresh state, preserving them in spirit of wine till he sent them to me.

The eye of the Eagle Owl presents in the most striking degree the peculiar characters of the class to which it belongs. The first of these are its shape and size, too well known to require description, adapted as they are to the very shallow cavities of the orbits.

In the Egyptian Vulture the pyramidal shape of the eye is less remarkable, and a slight approach is observable in it to the spherical globe. In the Buzzard this is still more marked, and the eye resembles as much the eye of the Pigeon as it does that of the Eagle Owl.

In examination of specimens which have been preserved in spirit, it is necessary to restore the pliancy of the tissues of the ciliary muscle by allowing them to remain in water for some days; and I may observe that as this condition must be obtained in order to make satisfactory preparations, the method of using solutions of chromic acid or the bichromate of potash to enable the anatomist to make sections is not to be recommended, if the object be to ascertain the dimensions of the muscle and the elasticity of the ligament, which will be presently described. It need hardly be stated that the best mode of treating the eye is to freeze it and then make sections.

The strong plates of bone which exist in the sclerotic of birds preserve the shape of the eye sufficiently well to allow of the dimensions being ascertained after it has been preserved in spirit.

In the Eagle Owl the dimensions are as follow:—

	in.
Diameter of cornea	$\frac{7}{8}$
Diameter of base of eye	$1\frac{9}{32}$
Antero-posterior length	$1\frac{6}{16}$
Lateral diameter of lens	$\frac{9}{16}$
Antero-posterior diameter of lens	$\frac{1}{2}$

The shape of the lens does not appear to be altered by the action of alcohol; but the size is diminished, and the measurements just stated are less than they would be found to be if the lens had been perfectly fresh.

The eye is first to be divided into equal halves by cutting through the sclerotic, choroid, cornea, and iris. We may regard the sclerotic as a hollow case enclosing a sphere, of which the choroid is the proper covering, and which sphere is attached to its case by tissues of highly elastic and muscular properties, by which a certain amount of movement is capable of being effected in the parts on which the formation of the image depends. It is to be observed, however, that the posterior surface of the choroid is kept in close apposition with the inner and posterior surface of the sclerotic, so that movement of the anterior parts is not communicated to that part on which the optic nerve is expanded. In the eye of the Eagle Owl these conditions are obtained in the following manner.

The whole of the posterior surface of the choroid which corresponds to the optic disk is kept in close apposition to the sclerotic by the direct attachment of the circumference of the part immediately beneath the

margin of the retina; it is also fixed where the nerve passes through the sclerotic, while delicate fibres from the choroid keep it in its position at other points.

The anterior part of the choroid, on the contrary, is not in contact with the sclerotic, as the ciliary muscle and the structure I have termed the posterior elastic ligament intervene.

This division of the choroid is not artificial, but is clearly defined by a difference of structure. The posterior part is but slightly vascular, is not elastic, is of considerable tenuity, and has greater resemblance in its general characters to the choroid of fish than to that of the mammalia.

The anterior portion is covered on its internal surface by the ciliary processes, which extend to the angle of curvature of the posterior part of the eye. The tissue of this part of the choroid is of peculiar character; it is dense, strong, and inelastic, and appears to be composed of delicate fibrous tissue. The combination of these characters enables it to preserve its symmetrical shape, and ensure to some degree the preservation of the structures within it. It possesses a rigidity which may be compared to that of ordinary writing-paper, and is of about the same thickness. The anterior part of the choroid is attached to the sclerotic by another structure—a system of fine elastic fibres which pass from the corneal margin of the sclerotic to the line of union between the iris and the choroid, and for which I proposed the name of anterior elastic filaments. Between the anterior elastic filaments and the posterior elastic ligament (a distance in the eye of the Eagle Owl of nearly five eighths of an inch) is interposed the ciliary muscle. The body of the muscle is attached to the line of union of the sclerotic and cornea, so that it may be said to arise from the anterior angle of curvature. The greater part of the posterior portion of the muscle is of delicate tendinous structure; its line of insertion into the choroid is the same as, but on the opposite side of, the line of insertion of the posterior elastic ligament. The breadth of the latter structure is about one eighth of an inch, while the length of the anterior elastic filaments is nearly the same. Thus, passing from before backwards, we have the anterior elastic filaments, the body of the ciliary muscle, its long delicate tendinous portion, and lastly the posterior elastic ligament. To exhibit the structures satisfactorily, the best plan is to make a section of the choroid and sclerotic of one sixteenth of an inch in thickness, and after fixing the two ends of the section on a layer of cork with needles, to dissect the muscle under water or alcohol—a very simple process if a magnifying-glass of an inch focus is employed. It is only necessary to draw the iris gently away from the sclerotic so as to extend the anterior elastic filaments, fixing it with a needle, and then to do the same with the choroid, taking care to hold that membrane at a point posterior to the line of insertion of the posterior elastic ligament.

The length of the ciliary muscle is about three eighths of an inch. I have attempted to preserve sections made in this way in Canada balsam, but

have found that rupture of the ligament usually takes place, I presume from its tenacity being destroyed by the action of the fluid. It is on that part of the choroid which lies between its two lines of attachment, on its internal surface, that the ciliary processes are developed, and to the anterior part of those processes that the crystalline lens is attached. Contraction of the ciliary muscle, it is reasonable to suppose, would produce a change in the position of the lens, and would take place when the object to which the sight was directed was close to the eye—that is to say, the muscle is employed in accommodation for short range of vision. The position of rest is restored by the posterior elastic ligament, which acts in direct opposition to the muscle.

The eye of the Vulture is smaller than that of the Owl, is not so decidedly pyramidal in shape, and may be placed between the latter and the eye of the Buzzard. The chief difference, however, between them is in the greater degree of concavity which the posterior portion of the sclerotic assumes; so that in the Owl the retina lies on a flatter surface than in the Buzzard, while in that respect the Vulture is between the two.

The dimensions of the eye of the Vulture are as follow :—

	in.
Diameter of cornea	$\frac{9}{16}$
Lateral diameter of the sclerotic in its broadest part	$1\frac{3}{16}$
Antero-posterior diameter of eye	$\frac{15}{16}$
Length of ciliary muscle	$\frac{9}{32}$
Breadth of the posterior elastic ligament	$\frac{1}{10}$

Length of the anterior elastic filaments approximately the same.

With regard to the anterior elastic filaments and the posterior elastic ligament, it is unnecessary to make further remark, beyond that they resemble those structures in the eye of the Owl.

In the Buzzard the dimensions of the eye and its structures are as follow :—

	in.
Diameter of cornea	$\frac{4}{10}$
Lateral diameter of eye	1
Antero-posterior diameter of eye	$\frac{3}{4}$
Length of ciliary muscle	$\frac{3}{16}$
Length of posterior elastic ligament }	$\frac{1}{16}$
Length of anterior elastic filament }	

In order to ascertain the mechanical effect produced by the ciliary muscle, the simple experiment may be performed of applying traction, by means of a pair of forceps, on the choroid, the dissection being arranged and fixed as I have described. It will readily be seen that the elastic ligament acts in direct opposition to the muscle, and in the living eye has the power of restoring the parts to the condition of rest.

The ciliary muscle is composed of striated fibre of very distinct character.

It varies, as is seen in the three examples described, in length and amount of muscular tissue. The tendon in the Owl is long and the body of the muscle short; but in the other species, as in most birds, the muscular fibres extend to a great length, if not entirely from the origin to the insertion of the muscle. These minute differences should be pointed out in detail in the case of each species of bird.

The elastic ligament is composed of very delicate elastic tissue, the microscopical character of which is well defined.

On the peculiar nature of the anterior elastic filaments I beg to postpone any decided opinion.

With regard to the nerves which supply the ciliary muscle and the iris, I have no particular remarks to offer, as the description which I gave some years ago of the ganglia and plexuses on the ciliary nerves in the eye of the Pheasant will apply generally to all birds. Whether the contraction of the iris and the accommodation of the sight be voluntary or involuntary actions on the part of birds we cannot say positively; I am inclined to believe that the latter is the case.

For the sake of convenience, and to render any further researches on the dimensions of the different parts of the eye in other species of birds symmetrical with those contained in this communication, I have arranged the principal facts in the following tabulated form:—

	Eagle Owl.	Egyptian Vulture.	Buzzard.
Diameter of cornea	·875	·506	·4
Greatest diameter of sclerotic (transversely)	1·312	1·182	1
Antero-posterior diameter	1·375	·932	·75
Diameter of lens (transversely)	·506	Not recorded.	·343
Antero-posteriorly	·5	....	·22
Length of ciliary muscle	·375	·3	·187
Breadth of posterior elastic ligament	·125	·1	·063
Length of anterior elastic filaments .	·125	·1	·063
Character of ciliary muscle	Body short, tendon long.	Muscular fibres form more than three fourths of it.	Muscular fibres extend from origin to insertion.

From the above Table we may draw the following conclusions:—that in the Eagle Owl the range of vision is small, the power of accommodation very rapid; in the Vulture range of vision is great, the power of accom-

modation considerable, but slower than in the Owl; in the Buzzard the range of vision is greater still, and the power of accommodation capable of being readily and extensively exercised.

These conclusions, I think, will be found to accord with the observations of those who have had opportunities of making themselves acquainted with the habits of the birds during life.

It has been usual for those who have devoted much attention to the physiology of vision to propose some original and independent explanation of the means by which accommodation for distance is effected, if their researches have been attended with the observation of any previously unknown facts connected with the subject, either experimental or anatomical. It appears to me that as yet we have not sufficient data to afford a perfectly satisfactory explanation of that remarkable property possessed by the eye, partly on account of the difficulty of ascertaining the exact functions of different structures, and particularly by reason of the very various conditions which the same structures assume in various species of vertebrate animals. The line of investigation which is pointed out in this communication it is by no means certain will assist in the solution of the problem of the means by which adjustment for distance is effected; but I am inclined to think that we have not yet exhausted all the resources which careful anatomical inquiry places at our command, and that when a sufficient number of details have been collected, the subject will be in a more suitable state for the application of optical laws than it is at present.

Supplement, containing a Description of the Eye in *Rhea americana, Phœnicopterus antiquorum,* and *Aptenodytes Humboldtii.* Received April 27, 1872.

In the American Ostrich the eye is large, and the structures concerned in the adjustment for distance are well developed. In the Ostrich (*Struthio camelus*) the observation was first made by Sir P. Crampton of the existence of the ciliary muscle; and as the views of physiologists regarding the mechanical functions of the muscle in the accommodation of sight were various, while numerous inquiries were made very soon after the publication of this new anatomical fact, I am gratified in having the opportunity of pointing out the cause of the discrepancies in opinion which have continued to the present time.

The description which Crampton has given is correct so far as it goes, but it was limited to that part of the ciliary muscle which forms the thickest portion of it, that is to say, the dense part which lies closest to the margin of the cornea. The tendon of the muscle and its insertion into the choroid were not observed by Crampton, and the structure termed the posterior elastic ligament was overlooked. It can thus be explained how it was that the deflection of the margin of the cornea and consequent

change in its curvature were advanced as the means by which accommodation was effected.

The eye of *Rhea americana* appears to be very similar to that of *Struthio camelus*, though not quite so large. The globe is of irregular shape, and bulges out both laterally and vertically; its diameter in the former direction is an inch and two thirds, in the latter an inch and a half, and antero-posteriorly an inch and one third.

The sclerotic is not particularly thick, and contains but slightly developed osseous structure. The crystalline lens is about half an inch in its lateral diameter, and one third of an inch in its antero-posterior diameter. The ciliary muscle is large and strong, the body thick, and the fibres diminishing in size as they become tendinous near their insertion; its length is $\frac{3}{16}$ inch.

The anterior and posterior elastic ligaments are each about $\frac{3}{16}$ inch in length, though it is to be understood that their elasticity is so great that they might be stretched to a considerably greater length.

In the first part of this communication I expressed some doubt regarding the microscopical character of the anterior elastic ligaments; indeed the term ligament was not applied to them, as they did not possess the same distinct character as the posterior elastic ligament.

In all the species of birds which have come under my observation, the microscopical character of the last-mentioned structure was the same. In the *Rhea* the anterior elastic filaments are distinctly composed of the same kind of elastic fibres; their colour is a light-grey; they coil up very readily when torn from one another with needles; they are to some extent covered with fine granular or spongy tissue, which at first conceals their elastic character; they are continuous and of equal diameter from their origin to their insertion, and are united more closely than in most birds, so that the filamentous character so clearly seen in the Owls is not observed.

A more complete investigation into the anatomy of this part of the subject allows of the conclusion that the anterior elastic filaments are composed of cellular and elastic tissue combined in different proportions, and that the differences in their strength, elasticity, and appearance depend on the collection of the filaments into fibres of varying sizes, or their approximation so as to form a continuous suspensory band between the iris and the cornea.

The iris in this bird is not composed entirely of muscular fibres as in many other genera, but is soft and spongy in its general character, and more like the iris in mammalia than in birds.

As it is desirable to limit myself to those particular structures which are concerned in the accommodation of the eye for distance, deferring for the present certain general conclusions which fresh observations are required to confirm, I shall leave to the consideration of the naturalist the subjoined facts arranged in a tabulated form, and which appear to me to be applicable to the explanation of the habits of the birds by anatomical peculiarities.

	Cornea.	Sclerotic.	Lens.	Ciliary Muscle.	Elastic ligament.	
					Posterior.	Anterior.
	in.	in.	in.	in.	in.	in.
Rhea americana.........	vertical $\frac{20}{32}$	vertical $1\frac{1}{2}$	lateral $\frac{17}{32}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{3}{16}$
	lateral $\frac{22}{32}$	lateral $1\frac{14}{20}$				
		ant.-post. $1\frac{7}{20}$	ant.-post. $\frac{11}{32}$	fibres long.		
Phœnicopterus antiquorum	vertical $\frac{12}{32}$	lateral $\frac{21}{32}$	lateral $\frac{8}{32}$	$\frac{1}{16}$	$\frac{3}{64}$	$\frac{3}{64}$
	lateral $\frac{1}{64}$ more	ant.-post. $\frac{18}{32}$	ant.-post. $\frac{5}{32}$	gradually diminishing.		
Aptenodytes Humboldtii	$\frac{11}{32}$	lateral $\frac{14}{16}$	lateral $\frac{9}{32}$	$\frac{2}{16}$	$\frac{2}{16}$	$\frac{2}{16}$
		ant.-post. $\frac{12}{16}$	ant.-post. $\frac{8}{32}$	gradually diminishing.		

The Society then adjourned over the Whitsuntide Recess to Thursday, May 30.

May 30, 1872.

GEORGE BIDDELL AIRY, C.B., President, in the Chair.

THE BAKERIAN LECTURE was delivered by WILLIAM KITCHEN PARKER, F.R.S., "On the Structure and Development of the Skull of the Salmon (*Salmo salar*, L.)." The following is an Abstract.

A few years ago Mr. Waterhouse Hawkins put into my hands some newly hatched salmon and also three of the first summer. Seeing their fitness for embryological research and the interest attaching to the formation of an osseous fish, I applied to my friends Messrs. Frank Buckland and Henry Lee, and these gentlemen most liberally supplied me with a large number of unhatched embryos and of the "fry" of this large fish.

My last subject, the frog, being fairly out of hand, I set myself last summer to this newer and more easy task,—more easy by far, for the translucency of the young salmon contrasts most favourably with the obscurity of the embryo frog.

I found that the two types at the time of hatching did not start fairly, but that the salmon had hastened to finish its *fourth stage* before emerging from the egg; this, however, is partly in consequence of the difference of the envelope in which the embryos are contained; for in the salmon this is a leathery "chorion," and in the frog a mere gelatinous bleb.

Moreover, it soon became apparent that these two "Ichthyopsidans" are