E

E is the second vowel-symbol and the fifth letter in our alphabet. In its original form among the Phœnicians it represented the rough breathing—our *h*: we have seen that A represented the smooth breathing. As the Greeks had the sound *h* at a very early period, it might have been expected that this symbol would have been taken by them with its original value. But the want of symbols to denote the vowels was apparently felt to be more imperative; therefore all the Phœnician symbols (corresponding to the Hebrew aleph, he, ayin) were taken to denote the vowel-sounds *a*, *e*, *o* respectively. The form of the symbol E has varied little from the earliest Greek times to our own. In old Latin it is sometimes, but rarely, found in the form ||. The typical sound of E in almost all languages is one of those which we denote generally by *a* in English, *e.g.*, in the word *fate*—that is, one of the simple sounds between A (English *ah*) and I (English *ee*), which are produced by raising the tongue gradually from its lowest position (at A) to its highest position (at I): in this scale of sounds the lips are not employed. The most clearly distinguished of these sounds are (1) that in *men*, (2) that in *fair*, (3) that in *fate*. It will be observed that these sounds have here different symbols; and if these were consistently employed in English we should not have much reason to complain of our spelling; but *e* has also the I-sound in *here* and *see*; *ai* in *wait* has the same sound as *a* in *fate*; and *a* has many sounds. Other languages employ diacritical marks to distinguish these sounds; thus in Italian we have *è* and *é*, called "open" and "close" *e* respectively; these correspond very nearly to (2) and (3) mentioned above. It is probable that the same distinction of sound was given in Latin by employing *ae* to express the open *e*: at least open *e* is commonly found in Italian words which were written in Latin with *ae*, or with *e* short. It is possible that in Greece a similar distinction of close open *e* was expressed in early times by the symbols ε (epsilon) and η (eta); but in Attica, at least after 403 B.C., the distinction seems to have been rather quantitative than qualitative. For the history of eta see article H. It is clear that in a perfect alphabet we ought to have at least three distinct symbols between A and I: we ought not to be compelled to distinguish the simple sounds by diphthongs or other modifications. Indeed yet more symbols would be desirable, for there are other sounds in this scale, which, however, are not easily distinguished from the above except by a practised ear.

It is probable that *ee* in English of the 16th and 17th centuries had the sound still heard in Scotland in words like *ell*, *i.e.*, the simple *e* in our *men* pronounced long: this is not unlike the open-*e*, but the back of the tongue is lower. But *ee* had acquired its present I sound in the last century.

EACHARD, John (1636–1697), an English divine, was born in Suffolk in 1636, and was educated at Catherine Hall, Cambridge, of which he became master in 1675 in succession to Lightfoot. He was created a doctor of divinity in 1676 by royal mandate, and was twice (in 1679 and 1695) vice-chancellor of the university. He died on the 7th July 1697. In 1670 he had published anonymously a humorous satire entitled *The Ground and Occasions of the Contempt of the Clergy enquired into in a letter to R. L.*, which excited much attention and provoked several replies, one of them being from John Owen. These were met by *Some Observations, etc., in a second letter to R. L.* (1671), written in the same bantering tone as the original work. Eachard attributed the contempt into which the clergy had fallen to their imperfect education, their insufficient incomes, and the want of a true vocation. He gave amusing illustrations of the absurdity and poverty of the current pulpit oratory of his day, some of them being taken from the sermons of his own father. He attacked the philosophy of Hobbes in his *Mr Hobbs's State of Nature considered, in a dialogue between Philautus and Timothy* (1672), and in his *Some Opinions of Mr Hobbs considered in a second dialogue* (1673). These were written in their author's chosen vein of light satire, and Dryden praised them as highly effective within their own range. It is noteworthy that Eachard's own sermons were not superior to those he satirized. Swift alludes to him as a signal instance of a successful humorist who entirely failed as a serious writer. A collected edition of his works in three volumes, with a notice of his life, was published in 1774.

EADIE, John (1810–1876), theologian and biblical critic, was born at Alva, in Stirlingshire, on the 9th May 1810. Having manifested unusual ability at school, he was sent to the university of Glasgow, where he passed through the usual curriculum in arts. Immediately afterwards he commenced to study for the ministry at the Divinity Hall of the Secession Church, a dissenting body which, on its union a few years later with the Relief Church, adopted the denomination United Presbyterian. In 1835 he was ordained to the pastoral charge of the Cambridge Street Secession church in Glasgow. Here he speedily attained a position of great eminence and usefulness, and for many years before the close of his life he was generally regarded as the leading representative of his denomination in the city which has always been its stronghold. Though he had little claim to be called eloquent, and his style was often slovenly, he had many of the other qualities that secure the most useful and enduring kind of popularity. As a preacher he was distinguished by invariable good sense, frequent flashes of happy illustration, masculine piety, deep spiritual earnestness, breadth of sympathy both intellectual and emotional, and—most specifically of all—by the power he had in his expository discourses of conveying the best results of biblical criticism in an intelligible form to a general audience. Behind the carelessness and apparent indifference of his manner, it was not difficult to detect the quick sensibility and tender feeling which were eminently characteristic of the man. Though more than once invited to an important charge elsewhere, Dr Eadie refused to leave Glasgow, in which he found a sphere more exactly suited to his pastoral gifts than he could expect in any other place. In 1863 he removed with a portion of his congregation to a new and beautiful church at Lansdowne Crescent, where his influence continued unabated until his death.

From his student days Eadie bore a reputation for extensive, if not profound and accurate, scholarship, which he justified and increased during the earlier years of his ministry to such an extent that in 1843 the church to which he belonged appointed him professor of biblical literature and hermeneutics in its Divinity Hall. He held this appointment along with his ministerial charge till the close of his life, and discharged its duties with an efficiency that was universally acknowledged. While his scholarship was not minute or thorough, he was surpassed by few biblical commentators of his day in range of learning, and by still fewer in the soundness of judgment with which his learning was applied. As a critic he was acute and painstaking; as an interpreter he was eminently fair-minded. In the professor's chair, as in the pulpit, his strength lay in the tact with which he selected the soundest results of biblical criticism, whether his own or that of others, and presented them in a clear and connected form, with a constant view to their practical bearing. If this last fact gave a non-academic aspect to some portions of his lectures, it rendered them not less interesting and probably not less useful to his auditors. Eadie's merits as a scholar were early acknowledged by the usual honorary university distinctions. He received the degree of LL.D. from Glasgow in 1844, and that of D.D. from St Andrews in 1850.

Busily engaged as he was in two distinct offices, either of which might well of itself have employed all his energies, Eadie nevertheless found time for an amount of work in a third sphere, of which the same thing might be said. His labours as an author would have been more than creditable to one who had no other occupation. Most of his works were connected with biblical criticism and interpretation, some of them being designed for popular use and others being more strictly scientific. To the former class belong the *Biblical Cyclopædia*, his edition of *Cruden's Concordance*, his *Early Oriental History*, and his discourses on *The Divine Love* and on *Paul the Preacher*; to the latter belong his commentaries on the Greek text of St Paul's epistles to the Ephesians, Colossians, Philippians, and Galatians, published at intervals in four volumes, which take a high rank among exegetical works. His *Life of Dr Kitto* obtained a deserved popularity. His last work, the *History of the English Bible* (2 vols. 1876), will probably be the most enduring memorial of his ability as an author. Though not unimpeachable in point of arrangement and style, it contains a fuller and more accurate account of the subject than is to be found anywhere else, and almost every page bears marks of the life-long interest and loving research of the author. His almost unrivalled knowledge of the various English versions, as well as his ability as a critic and interpreter of the original, led to his being selected as one of the company for the revision of the authorized version of the New Testament, and in this capacity it is understood that he rendered excellent service. Dr Eadie died at Glasgow on the 3d June 1876.

EADMER, or Edmer (in Latin Eadmerus, and by mistake Edimerus and Edinerus), an English ecclesiastic and historian of the Norman period, probably, as his name suggests, of English as opposed to Norman parentage. At an early age he was sent to the Benedictine monastery at Canterbury; and there he became acquainted with Anselm, at the time of the latter's first visit to England as abbot of Bec. The intimacy was renewed when Anselm was raised to the episcopal see; and thenceforward Eadmer was not so much the archbishop's disciple and follower as his friend and director, and that at last not only by Anselm's private recognition, but by the formal appointment of Pope Urban II. So complete, indeed, was the obedience shown by the great scholastic philosopher and head of the English Church to his self-elected tutor, that—according to William of Malmesbury, *De gestis pontificum Anglorum*, lib. i.—he is said to have waited for his express permission before he rose from his bed, or even turned from one side to the other. After Anselm's death Eadmer accompanied Radulph, the new archbishop, to Rome in 1119; and on their return in 1120 he was nominated to the see of St Andrews in Scotland. Owing, however, to the refusal of the Scotch to recognize the claims put forward by Eadmer and his patron in support of the episcopal authority of the see of Canterbury, he was never formally inducted into the office. He was at Canterbury in 1121, and he spent the latter part of his life as prior of the monastery there. His death is variously assigned to the year 1123 and 1137.

Eadmer has left a large number of works, of which a list is given in Wharton's *Anglia Sacra*, part ii. Most important are his *Historiæ Novorum*, in six books treating of his own times down to the death of Radulph in 1122, and his *Vita Anselmi*, which ranks as one of the chief authorities in regard to the primate. The former was first published by Selden in 1623, the latter at Antwerp in 1551; and both have since been several times reprinted. Of less mark are his lives of Odo, Bregwin, and Dunstan, and of Oswald and Wilfrid of York, and his treatises—formerly ascribed to Anselm—*De quatuor virtutibus quæ fuerunt in beata Maria virgine*, and *De Similitudinibus S. Anselmi*. Nearly all his works are to be found in an early MS. in the library of Corpus Christi College, Cambridge (C.C.C.C., No 371), and most of them have been reprinted as an appendix to Anselm's *Opera* by Gerberon, fol. 1675, and by the Benedictine monks of St Maure, fol. Paris, 1721. A number of his letters are preserved in MSS. Cotton., Otho, A. xii.

See especially Wright, *Biographia Brit. Lit.*, Anglo-Norman Period, 1846; Charma, *Saint Anselm*, 1853, pp. 186, 187; Burton, *History of Scotland*, vol. i. pp. 422–424.

EAGLE (French *Aigle*, from the Latin *Aquila*), the name generally given to the larger Diurnal Birds-of-prey which are not Vultures; but the limits of the subfamily *Aquilinæ* have been very variously assigned by different writers on systematic ornithology, and, as before observed (Buzzard, vol. iv. p. 603), there are Eagles smaller than certain Buzzards. By some authorities the *Læmmergeier* of the Alps, and other high mountains of Europe, North Africa, and Asia, is accounted an Eagle, but by others the genus *Gypaetus* is placed with the *Vulturidæ*, as its common English name (Bearded Vulture) shows. There are also other forms, such as the South-American *Harpyia* and its allies, which though generally called Eagles have been ranked as Buzzards. In the absence of any truly scientific definition of the family *Aquilinæ* it is best to leave these and many other more or less questionable members of the group—such as the genera *Spizaetus*, *Circaetus*, *Spilornis*, *Helotarsus*, and so forth—and, so far as space will allow, to treat here of those whose position cannot be gainsaid.

True Eagles inhabit all the Regions of the world, and some seven or eight species at least are found in Europe, of which two are resident in the British Islands. In England and in the Lowlands of Scotland Eagles only exist as stragglers; but in the Hebrides and some parts of the Highlands a good many may yet be found, and their numbers appear to have rather increased of late years than diminished, for the foresters and shepherds, finding that a high price can be got for their eggs, take care to protect the owners of the eyries, which are nearly all well known, and to keep up the stock by allowing them at times to rear their young. There are also now not a few occupiers of Scottish forests who interfere so far as they can to protect the king of birds. But hardly twenty years ago trapping, poisoning, and other destructive devices were resorted to without stint, and there was then every probability that before long not an Eagle would be left to add the wild majesty of its appearance to the associations of the mountain or the lake.[1] In Ireland the extirpation of Eagles seems to have been carried on almost unaffected by the prudent considerations which in the northern kingdom have operated so favourably for the race, and except in the wildest parts of Donegal, Mayo, and Kerry, Eagles in the sister-island are said to be almost birds of the past.

Of the two British species the Erne (Icel. *Œrn*) or Sea-

[1] The late Lord Breadalbane was perhaps the first large landowner who set the example that has been since followed by others. On his unrivalled forest of Black Mount, Eagles—elsewhere persecuted to the death—were by him ordered to be unmolested so long as they were not numerous enough to cause considerable depredations on the farmers' flocks. He thought, and all who have an eye for the harmonies of nature will agree with him, that the spectacle of a soaring Eagle was a fitting adjunct to the grandeur of his Argyllshire mountain-scenery, and a good equivalent for the occasional loss of a lamb, or the slight deduction from the rent paid by his tenantry in consequence. How faithfully his wishes were carried out by his head-forester, Mr Peter Robertson, the present writer has abundant means of knowing.

Eagle (by some called also the White-tailed and Cinereous Eagle)—*Haliaetus albicilla*—affects chiefly the coast and neighbourhood of inland waters, living in great part on the fish and refuse that is thrown up on the shore, though it not unfrequently takes living prey, such as lambs, hares, and rabbits. On these last, indeed, young examples mostly feed when they wander southward in autumn, as they

FIG. 1.—Sea-Eagle.

yearly do, and appear in England. The adults (fig. 1) are distinguished by their prevalent greyish-brown colour, their pale head, yellow beak, and white tail—characters, however, wanting in the immature, which do not assume the perfect plumage for some three or four years. The eyry is commonly placed in a high cliff or on an island in a lake—sometimes on the ground, at others in a tree—and consists of a vast mass of sticks, in the midst of which is formed a hollow lined with *Luzula sylvatica* (as first observed by the late Mr John Wolley) or some similar grass, and here are laid the two or three white eggs. In former days the Sea-Eagle seems to have bred in several parts of England—as the Lake district, and possibly even in the Isle of Wight and on Dartmoor. This species inhabits all the northern part of the Old World from Iceland to Kamchatka, and breeds in Europe so far to the southward as Albania. In the New World, however, it is only found in Greenland, being elsewhere replaced by the White-headed or Bald Eagle, *H. leucocephalus*, a bird of similar habits, and the chosen emblem of the United States of America. In the far east of Asia occurs a still larger and finer Sea-Eagle, *H. pelagicus*, remarkable for its white thighs and upper wing-coverts. South-eastern Europe and India furnish a much smaller species, *H. leucoryphus*, which has its representative, *H. leucogaster*, in the Malay Archipelago and Australia, and, as allies in South Africa and Madagascar, *H. vocifer* and *H. vociferoides* respectively. All these Eagles may be distinguished by their scaly tarsi, while the group next to be treated of have the tarsi feathered to the toes.

The Golden or Mountain-Eagle, *Aquila chrysaetus*, is the second British species. This also formerly inhabited England, and a nest, found in 1668 in the Peak of Derbyshire, is well described by Willughby, in whose time it was said to breed also in the Snowdon range. It seldom if ever frequents the coast, and is more active on the wing than the Sea-Eagle, being able to take some birds as they fly, but a large part of its sustenance is the flesh of animals that die a natural death. Its eyry is generally placed and built like that of the other British species,[1] but the

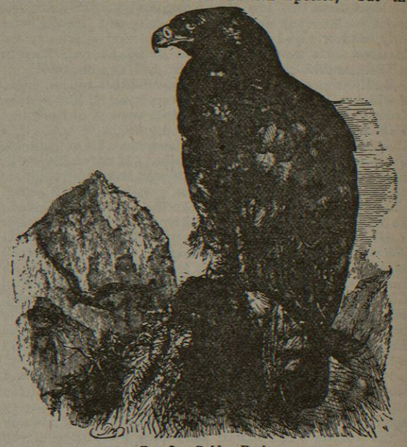

FIG. 2.—Golden Eagle.

neighbourhood of water is not requisite. The eggs, from two to four in number, vary from a pure white to a mottled, and often highly-coloured, surface, on which appear different shades of red and purple. The adult bird (fig. 2) is of a rich, dark brown, with the elongated feathers of the neck, especially on the nape, light tawny, in which imagination sees a "golden" hue, and the tail marbled with brown and ashy-grey. In the young the tail is white at the base, and the neck has scarcely any tawny tint. The Golden Eagle does not occur in Iceland, but occupies suitable situations over the rest of the Palæarctic Region and a considerable portion of the Nearctic—though the American bird has been, by some, considered a distinct species. Domesticated, it has many times been trained to take prey for its master in Europe, and to this species is thought to belong an Eagle habitually used by the Kirgiz Tartars, who call it *Bergut* or *Bearcoot*, for the capture of antelopes, foxes, and wolves. It is carried hooded on horseback or on a perch between two men, and released when the quarry is in sight. Such a bird, when well trained, is valued, says Pallas, at the price of two camels. It is quite possible, however, that more than one kind of Eagle is thus used, and the services of *A. hehiaca* (which is the Imperial Eagle of some writers[2]) and of *A. mogilnik*—

[1] As already stated, the site chosen varies greatly. Occasionally placed in a niche in what passes for a perpendicular cliff to which access could only be gained by a skilful cragsman with a rope, the writer has known a nest to within ten or fifteen yards of which he rode on a pony. Two beautiful views of as many Golden Eagle's nests, drawn on the spot by Mr Wolf, are given in the *Cothecа Wolleyana*, and a fine series of eggs is also figured in the same work.

[2] Which species may have been the traditional emblem of Roman power, and the *Ales Jovis*, is very uncertain.

both of which are found in Central Asia, as well as in South-eastern Europe—may also be employed.

Of the other more or less nearly allied species or races want of room forbids the consideration, but there is a smaller form on which a few words may be said. This has usually gone under the name of *A. nævia*, but is now thought by the best authorities to include three local races, or, in the eyes of some, species. They inhabit Europe, North Africa, and Western Asia to India, and two examples of one of them—*A. clanga*, the form which is somewhat plentiful in North-eastern Germany—have occurred in Cornwall. The smallest true Eagle is *A. pennata*, which inhabits Southern Europe, Africa, and India. Differing from other Eagles of their genus by its wedge-shaped tail, though otherwise greatly resembling them, is the *A. audax* of Australia. Lastly may be noticed here a small group of Eagles, characterized by their long legs, forming the genus *Nisaetus*, of which one species, *N. fasciatus*, is found in Europe. The Osprey (*Pandion*), though placed by many among the *Aquilinæ*, certainly does not belong to that subfamily. (A. N.)

EAR. The simplest form of the organ of hearing is a small sac containing fluid, with the auditory nerve expanded upon it. Sonorous vibrations are communicated to this sac either directly through the hard parts of the head, or at the same time by a membrane exposed to the surrounding medium. Such is the form of ear found in many of the Crustacea and in the Cephalopoda. In the Vertebrata, there is a progressive development and increasing complexity from the fishes up to Mammalia. For details as to the structure of the ear in the different subdivisions of the Vertebrata, reference is made to the articles treating of these, such as AMPHIBIA, BIRDS, &c.; and the structure of the human ear will be found fully described in the article ANATOMY, vol. i. p. 891.* It is the object of this article to describe the phenomena of auditory sensation from the physiological point of view.

The sense of hearing is a special sensation the cause of which is an excitation of the auditory nerves by the vibrations of sonorous bodies. A description of sonorous vibrations and of their transmission is given in the article ACOUSTICS; here we shall consider, first, the transmission of such vibrations from the external ear to the auditory nerve, and secondly, the physiological characters of auditory sensation.

I.—1. *Transmission in External Ear.*—The external ear consists of the *pinna*, or auricle, and the *external auditory meatus*, or canal, at the bottom of which we find the *membrana tympani*, or drum head. In many animals the auricle is trumpet-shaped, and, being freely movable by muscles, serves to collect sonorous waves coming from various directions. The auricle of the human ear presents many irregularities of surface. If these irregularities are abolished by filling them up with a soft material such as wax or oil, leaving the entrance to the canal free, experiment shows that the intensity of sounds is weakened, and that there is more difficulty in judging of their direction. When waves of sound strike the auricle, they are partly reflected outwards, while the remainder, impinging at various angles, undergo a number of reflections so as to be directed into the auditory canal. Vibrations are transmitted along the auditory canal, partly by the air it contains and partly by its walls, to the membrana tympani. The absence of the auricle, as the result of accident or injury, has not caused diminution of hearing. In the auditory canal, waves of sound are reflected from side to side until they reach the membrana tympani. From the obliquity in position and peculiar curvature of this membrane, most of the waves must strike it nearly perpendicularly, and in the most advantageous direction.

2. *Transmission in Middle Ear.*—The middle ear is a small cavity, the walls of which are rigid with the exception of the portions consisting of the membrana tympani, and the membrane of the round window and of the apparatus filling the oval window. This cavity communicates with the pharynx by the *Eustachian tube*, which forms a kind of air-tube between the pharynx and the tympanum for the purpose of regulating pressure on the membrana tympani. It is generally supposed that during rest the tube is open, and that it is closed during the act of deglutition. As this action is frequently taking place, not only when food or drink is introduced, but when saliva is swallowed, it is evident that the pressure of the air in the tympanum will be kept in a state of equilibrium with that of the external air on the outer surface of the membrana tympani, and that thus the membrana tympani will be rendered independent of variations of atmospheric pressure such as may occur within certain limits, as when we descend in a diving bell or ascend in a balloon. By a forcible expiration, the oral and nasal cavities being closed, air may be driven into the tympanum, while a forcible inspiration (Valsalva's experiment) will draw air from that cavity. In the first case, the membrana tympani will bulge outwards, in the second case inwards, and in both, from excessive stretching of the membrane, there will be partial deafness, especially for sounds of high pitch. Permanent occlusion of the tube is one of the most common causes of deafness

The membrana tympani is capable of being set into vibration by a sound of any pitch included in the range of perceptible sounds. It responds exactly as to number of vibrations (pitch), intensity of vibrations (intensity), and complexity of vibration (quality or timbre). Consequently we can hear a sound of any given pitch, of a certain intensity, and in its own specific timbre or quality. Generally speaking, very high tones are heard more easily than low tones of the same intensity. As the membrana tympani is not only fixed by its margin to a ring or tube of bone, but is also adherent to the handle of the malleus, which follows its movements, its vibrations meet with considerable resistance. This diminishes the intensity of its vibrations, and prevents also the continued vibration of the membrane after an external vibration has ceased, so that a sound is not heard much longer than it lasts. The tension of the membrane may be affected (1) by differences of pressure on the two surfaces of the membrana tympani, as may occur during forcible expiration or inspiration, or in a pathological condition, and (2) by muscular action, due to contraction of the *tensor tympani* muscle. This small muscle arises from the apex of the petrous temporal and the cartilage of the Eustachian tube, enters the tympanum at its anterior wall, and is inserted into the malleus near its root. The handle of the malleus is inserted between the layers of the membrana tympani, and, as the malleus and incus move round an axis passing through the neck of the malleus from before backwards, the action of the muscle is to pull the membrana tympani inwards towards the tympanic cavity in the form of a cone, the meridians of which, according to Helmholtz, are not straight but curved, with convexity outwards. When the muscle contracts, the handle of the malleus is drawn still farther inwards, and thus a greater tension of the tympanic membrane is produced. On relaxation of the muscle, the membrane returns to its position of equilibrium by its own elasticity and by the elasticity of the chain of bones. This power of varying the tension of the membrane is a kind of accommodating mechanism for receiving and transmitting sounds of different pitch. With different degrees of tension, it will respond more readily to sounds of different pitch. Thus, when the membrane is tense, it will readily respond to high sounds, while relaxation will be the condition most

adapted for low sounds. In addition, increased tension of the membrane, by increasing the resistance, will diminish the intensity of vibrations. This is especially the case for sounds of low pitch.

Helmholtz has also pointed out that the peculiar form of the membrana tympani in man has the effect of increasing the force of its vibrations at the expense of their amplitude.

The vibrations of the membrana tympani are transmitted to the internal ear partly by the air which the middle ear or tympanum contains, and partly by the chain of bones, consisting of the malleus, incus, and stapes. Of these, transmission by the chain of bones is by far the most important. In birds and in the scaly amphibia, this chain is represented by a single rod-like ossicle, the *columella*, but in man the two membranes—the membrana tympani and the membrane filling the fenestra ovalis—are connected by a compound lever consisting of three bones, namely, the *malleus*, or hammer, inserted into the membrana tympani, the *incus*, or anvil, and the *stapes*, or stirrup, the base of which fits into the oval window. The lever thus formed has its fulcrum near the short process of the incus, which abuts against the tympanic wall; the power is applied at the handle of the malleus, and the resistance is at the base of the stirrup. Both by direct experimental observation and by calculation from data supplied by measurement of the lengths of the arms of the lever, Helmholtz has shown that by this arrangement vibrations are diminished in extent in the ratio of 3 to 2, but are inversely increased in force. Considering the great resistance offered to excursions of the stapes, such an arrangement must be advantageous. It must also be noted that in the transmission of vibrations of the membrana tympani to the fluid in the labyrinth or internal ear, through the oval window, the chain of ossicles vibrates as a whole and acts efficiently, although its length may be only a small fraction of the wave length of the sound transmitted.

3. *Transmission in the Internal Ear.*—The internal ear is composed of the labyrinth, formed of the vestibule or central part, the semicircular canals, and the cochlea, each of which consists of an osseous and a membranous portion (see vol. i. p. 893). The osseous labyrinth may be regarded as an osseous mould in the petrous portion of the temporal bone, lined by tesselated endothelium, and containing a small quantity of fluid called the *perilymph*. In this mould, partially surrounded by, and to some extent floating in, this fluid, there is the membranous labyrinth, in certain parts of which we find the terminal apparatus in connection with the auditory nerve, immersed in another fluid called the *endolymph*. The membranous labyrinth consists of a vestibular portion formed by two small sac-like dilatations, called the *saccule* and the *utricle*, the latter of which communicates with the semicircular canals by five openings. Each canal consists of a tube, bulging out at each extremity so as to form the so-called *ampulla*, in which, on a projecting ridge, called the *crista acoustica*, there are cells bearing or developed into long *auditory hairs*, which are to be regarded as the peripheral end-organs of the vestibular branches of the auditory nerve. The cochlear division of the membranous labyrinth consists of the *ductus cochlearis*, a tube of triangular form fitting in between the two cavities in the cochlea, called the *scala vestibuli*, because it commences in the vestibule, and the *scala tympani*, because it ends in the tympanum, at the round window. These two scalæ communicate at the apex of the cochlea. The roof of the ductus cochlearis is formed by a thin membrane called the *membrane of Reissner*, while its floor consists of the *basilar membrane*, on which we find the remarkable *organ of Corti*, which constitutes the terminal organ of the cochlear division of the auditory nerve, and which is fully described in vol. i. p. 894. It is sufficient to state here that this organ consists essentially of an arrangement of epithelial cells bearing hairs which are in communication with the terminal filaments of this portion of the auditory nerve, and that groups of these hairs pass through holes in a closely investing membrane, *membrana reticularis*, which may be supposed to act as a damping apparatus, so as quickly to stop their movements. The ductus cochlearis and the two scalæ are filled with fluid. Sonorous vibrations may reach the fluid in the labyrinth by three different ways—(1) by the osseous walls of the labyrinth, (2) by the air in the tympanum and the round window, and (3) by the base of the stapes inserted into the oval window.

When the head is plunged into water, or brought into direct contact with any vibrating body, vibrations must be transmitted directly. Vibrations of the air in the mouth and in the nasal passages are also communicated directly to the walls of the cranium, and thus pass to the labyrinth. In like manner, we may experience peculiar auditive sensations, such as blowing, rubbing, and hissing sounds, due to muscular contraction or to the passage of blood in vessels close to the auditory organ. It has not been satisfactorily made out to what extent, if any, vibrations may be communicated to the fluid in the labyrinth by the round window. There can be no doubt, however, that in ordinary hearing vibrations are communicated chiefly by the chain of bones. When the base of the stirrup is pushed into the oval window, the pressure in the labyrinth increases, the impulse passes along the scala vestibuli to the scala tympani, and, as the only mobile part of the wall of the labyrinth is the membrane covering the round window, this membrane is forced outwards; when the base of the stirrup passes outwards, a reverse action takes place. Thus the fluid of the labyrinth may receive a series of pulses or vibrations isochronous with the movements of the base of the stirrup, and these pulses affect the terminal apparatus in connection with the auditory nerve.

Since the size of the membranous labyrinth is so small, measuring, in man, not more than $\frac{1}{2}$ inch in length by $\frac{1}{8}$th inch in diameter at its widest part, and since it is a chamber consisting partly of conduits of very irregular form, it is impossible to state accurately the course of vibrations transmitted to it by impulses communicated from the base of the stirrup. In the cochlea, vibrations must pass from the saccule along the scala vestibuli to the apex, thus affecting the membrane of Reissner, which forms its roof; then, passing through the opening at the apex (the *helicotrema*), they must descend by the scala tympani to the round window, and affect in their passage the membrana basilaris, on which the organ of Corti is situated. From the round window impulses must be reflected backwards, but how they affect the advancing impulses is not known. But the problem is even more complex when we take into account the fact that impulses are transmitted simultaneously to the utricle and to the semicircular canals communicating with it by five openings. The mode of action of these vibrations or impulses upon the nervous terminations is still unknown; but to appreciate critically the hypothesis which has been advanced to explain it, it is necessary, in the first place, to refer to some of the general characters of auditory sensation.

4. Certain conditions are necessary for excitation of the auditory nerve sufficient to produce a sensation. In the first place, the vibrations must have a certain amplitude: if too feeble, no impression will be produced. The minimum limit has been stated to be the sensation caused by the falling of a ball of pith, 1 millegramme in weight, upon a smooth surface, such as glass, from a height of 1 millimetre at a distance of 91 millimetres from the ear.

In the next place, vibrations must have a certain duration to be perceived; and lastly, to excite a sensation of a continuous musical sound, a certain number of vibrations must occur in a given interval of time. The lower limit is about 30, and the upper about 30,000 vibrations per second. Below 30, the individual impulses may be observed, and above 30,000 few ears can detect any sound at all. The extreme upper limit is not more than 35,000 vibrations per second. Auditory sensations are of two kinds—noises and musical sounds. *Noises* are caused by impulses which are not regular in intensity or duration, or are not periodic, or they may be caused by a series of musical sounds occurring instantaneously so as to produce discords, as when we place our hand at random on the key-board of a piano. *Musical tones* are produced by periodic and regular vibrations. In musical sounds three characters are prominent—intensity, pitch, and quality. *Intensity* depends on the amplitude of the vibration, and a greater or lesser amplitude of the vibration will cause a corresponding movement of the transmitting apparatus, and a corresponding intensity of excitation of the terminal apparatus. *Pitch*, as a sensation, depends on the length of time in which a single vibration is executed, or, in other words, the number of vibrations in a given interval of time. The ear is capable of appreciating the relative pitch or height of a sound as compared with another, although it may not ascertain precisely the absolute height of a sound. What we call an acute or high tone is produced by a large number of vibrations, while a grave or low tone is caused by few. The musical tones which can be used with advantage range between 40 and 4000 vibrations per second, extending thus from 6 to 7 octaves. According to E. H. Weber, practised musicians can perceive a difference of pitch amounting even to only the $\frac{1}{618}$th of a semitone, but this is far beyond average attainment. *Quality* or *timbre* (or *Klang*) is that peculiar characteristic of a musical sound by which we may identify it as proceeding from a particular instrument or from a particular human voice. It depends on the fact that many waves of sound that reach the ear are really compound wave systems, built up of constituent waves, each of which is capable of exciting a sensation of a simple tone if it be singled out and reinforced by a resonator (see Acoustics), and which may sometimes be heard without a resonator, after special practice and tuition. Thus it appears that the ear must have some arrangement by which it resolves every wave system, however complex, into simple pendular vibrations. When we listen to a sound of any quality we recognize that it is of a certain pitch. This depends on the number of vibrations of one tone, predominant in intensity over the others, called the fundamental or ground tone, or first partial tone. The quality, or timbre, depends on the number and intensity of other tones added to it. These are termed *harmonic* or *partial tones*, and they are related to the first partial or fundamental tone in a very simple manner, being multiples of the fundamental tone: thus—

	Fundamental Tone.	Upper Partials or Harmonics.								
Notes	do^1	do^2	sol^2	do^3	mi^3	sol^3	sib^3	do^4	re^4	mi^4
Partial tones	1	2	3	4	5	6	7	8	9	10
Number of vibrations	33	66	99	132	165	198	231	264	297	330

When a simple tone or one free from partials, is heard, it gives rise to a simple, soft, somewhat insipid sensation, as may be obtained by blowing across the mouth of an open bottle or by a tuning fork. The lower partials added to the fundamental tone give softness combined with richness; while the higher, especially if they be very high, produce a brilliant and thrilling effect, as is caused by the brass instruments of an orchestra. Such being the facts, how may they be explained physiologically?

Little is yet known regarding the mode of action of the vibrations of the fluid in the labyrinth upon the terminal apparatus connected with the auditory nerve. There can be no doubt that it is a mechanical action, a true communication of impulses to delicate hair-like processes, by the movements of which the nervous filaments are irritated. In the human ear it has been estimated that there are about 3000 small arches formed by the *rods of Corti* (see Anatomy). Each arch rests on the basilar membrane, and supports rows of cells having minute hair-like processes somewhat resembling cilia. It would appear also that the filaments of the auditory nerve terminate in the basilar membrane, and possibly they may be connected with the hair-cells. At one time it was supposed by Helmholtz that these fibres of Corti were elastic and that they were tuned for particular sounds, so as to form a regular series corresponding to all the tones audible to the human ear. Thus 2800 fibres distributed over the tones of seven octaves would give 400 fibres for each octave, or nearly 33 for a semitone. Helmholtz has put forward the ingenious hypothesis that, when a pendular vibration reaches the ear, it excites by sympathetic vibration the fibre of Corti which is tuned for its proper number of vibrations. If, then, different fibres are tuned to tones of different pitch, it is evident that we have here a mechanism which, by exciting different nerve fibres, will give rise to sensations of pitch. When the vibration is not simple but compound, in consequence of the blending of vibrations corresponding to various harmonics or partial tones, the ear has the power of resolving this compound vibration into its elements. It can only do so by different fibres responding to the constituent vibrations of the sound,—one for the fundamental tone being stronger, and giving the sensation of a particular pitch or height to the sound, and the others, corresponding to the upper partial tones, being weaker, and causing special though undefined sensations, which are so blended together in consciousness as to terminate in a complex sensation of a tone of a certain quality or timbre. It would appear at first sight that 33 fibres of Corti for a semitone are not sufficient to enable us to detect all the gradations of pitch in that interval, since, as has been stated above, trained musicians may distinguish a difference of $\frac{1}{618}$th of a semitone. To meet this difficulty, Helmholtz states that if a sound is produced, the pitch of which may be supposed to come between two adjacent fibres of Corti, both of these will be set into sympathetic vibration, but the one which comes nearest to the pitch of the sound will vibrate with greater intensity than the other, and that consequently the pitch of that sound would be thus appreciated. These theoretical views of Helmholtz have derived much support from remarkable experiments of Hensen, who observed that certain hairs on the antennæ of *Mysis*, a Crustacean, when observed with a low miscroscopic power, vibrated with certain tones produced by a keyed horn. It was seen that certain tones of the horn set some hairs into strong vibration, and other tones other hairs. Each hair responded also to several tones of the horn. Thus one hair responded strongly to $d'\sharp$ and $d''\sharp$, more weakly to g, and very weakly to c. It was probably tuned to some pitch between d' and $d''\sharp$. (*Studien über das Gehörorgan der Decapoden*, Leipsic, 1863.)

Recent histological researches have led to a modification of this hypothesis. It has been found that the rods or arches of Corti are stiff structures, not adapted for vibrating, but apparently consisting of a kind of support for the hair cells. It is also known that there are no rods of Corti in the cochlea of birds, which apparently are capable nevertheless of appreciating pitch. Hensen and Helmholtz have now suggested the view that not only may the segments of the membrana basilaris be stretched more in the radial than

in the longitudinal direction, but different segments may be stretched radially with different degrees of tension so as to resemble a series of tense strings of gradually increasing length. Each string would then respond to a vibration of a particular pitch communicated to it by the hair-cells. The exact mechanism of the hair-cells and of the membrana reticularis, which looks like a damping apparatus, is unknown.

II. *Physiological Characters of Auditory Sensation.*—1. Under ordinary circumstances auditory sensations are referred to the outer world. When we hear a sound, we associate it with some external cause, and it appears to originate in a particular place, or to come in a particular direction. This feeling of *exteriority* of sound seems to require transmission through the membrana tympani. Sounds which are sent through the walls of the cranium, as when the head is immersed in, and the external auditory canals are filled with, water, appear to originate in the body itself. It is probable, however, that the external character of ordinary auditory sensations may be more the result of habit than due to any anatomical peculiarity of the ear itself.

2. An auditory sensation lasts a short time after the cessation of the exciting cause, so that a number of separate vibrations, each capable of exciting a distinct sensation if heard alone, may succeed each other so rapidly that they are fused into a single sensation. If we listen to the puffs of a syren, or to vibrating tongues of low pitch, the single sensation is usually produced by about 30 or 35 vibrations per second; but there can be no doubt, as was first pointed out by Helmholtz, that when we listen to beats of considerable intensity, produced by two adjacent tones of sufficiently high pitch, the ear may follow as many as 132 intermissions per second.

3. The sensibility of the ear for sounds of different pitch is not the same. It is more sensitive for acute than for grave sounds, and it is probable that the maximum degree of acuteness is for sounds produced by about 3000 vibrations per second, that is near $fa^5\sharp$. Sensibility as to pitch varies much with the individual and with the training to which he has subjected himself. Thus some musicians may detect a difference of $\frac{1}{1000}$th of the total number of vibrations, while other persons may have difficulty in appreciating a semitone. This power of appreciating differences of pitch is termed a correct or just ear, and there can be no doubt of its improvement by cultivation.

4. Hearing with two ears does not appear materially to influence auditive sensation, but probably the two organs are enabled, not only to correct each other's errors, but also to aid us in determining the locality from whence a sound originates. It is asserted by Fechner that one ear may perceive the same tone at a slightly higher pitch than the other, but this may probably be due to some slight pathological condition in one ear. If two tones, produced by two tuning forks of equal pitch, are produced one near each ear, there is a uniform single sensation; if one of the tuning forks be made to revolve round its axis in such a way that its tone increases and diminishes in intensity, neither fork is heard continuously, but both sound alternately, the fixed one being only audible when the revolving one is not. It is difficult to decide whether excitations of corresponding elements in the two ears can be distinguished from each other. It is probable that the resulting sensations may be distinguished, provided one of the generating tones differs from the other in intensity or quality, although it may be the same in pitch.

5. Hitherto we have considered only the audition of a single sound, but it is possible also to have simultaneous auditive sensations, as in musical harmony. It is difficult to ascertain what is the limit beyond which distinct auditory sensations may be perceived. We have in listening to an orchestra a multiplicity of sensations which produces a total effect, while, at the same time, we can with ease single out and notice attentively the tones of one or two special instruments. Thus the pleasure of music may arise partly from listening to simultaneous, and partly from the effect of contrast or suggestion in passing through successive, auditory sensations.

The principles of harmony belong to the subject of music, but it is necessary here briefly to refer to these from the physiological point of view. If two musical sounds reach the ear at the same moment, an agreeable or disagreeable sensation is experienced, which may be termed a *concord* or a *discord*, and it can be shown by experiment with the syren (see Acoustics) that this depends upon the vibrational numbers of the two tones. The octave (1:2), the twelfth (1:3), and double octave (1:4), are absolutely consonant sounds; the fifth (2:3) is said to be perfectly consonant; then follow, in the direction of dissonance, the fourth (3:4), major sixth (3.5), major third (4:5), minor sixth (5:8), and the minor third (5:6). Helmholtz has attempted to account for this by the application of his theory of *beats*.

Beats are observed when two sounds of nearly the same pitch are produced together, and the number of beats per second is equal to the difference of the number of vibrations of the two sounds. Beats give rise to a peculiarly disagreeable intermittent sensation, comparable to what is experienced on watching a flickering light, and the painful sensation may arise from intermittent irritation of the auditory nerve filaments. The maximum roughness of beats, according to Helmholtz, is attained by 33 per second; beyond 132 per second, the individual impulses are blended into one uniform auditory sensation. When two notes are sounded, say on a piano, not only may the first, fundamental, or prime tones beat, but partial tones of each of the primaries may beat also, and as the difference of pitch of two simultaneous sounds augments, the number of beats, both of prime tones and of harmonics, augments also. The physiological effect of beats, though these may not be individually distinguishable, is to give roughness to the ear. If harmonics or partial tones of prime tones coincide, there are no beats; if they do not coincide, the beats produced will give a character of roughness to the interval. Thus in the octave and twelfth, all the partial tones of the acute sound coincide with the partial tones of the grave sound; in the fourth, major sixth, and major third, only two pairs of the partial tones coincide, while in the minor sixth, minor third, and minor seventh, only one pair of the harmonics coincide. For details, see Helmholtz, *On Sensations of Tone as a Physiological Basis for the Theory of Music*, translated by Alexander J. Ellis, London, 1875.

Diseases of the Ear.—Deafness may arise from obstruction of the external ear occasioned by disease of various kinds; from ulceration, thickening, or perforation of the membrana tympani; from inflammatory affections, both acute and chronic, of the middle and internal ear; from obstruction of the Eustachian tube caused by inflammation of its lining membrane, leading to thickening and accumulation of mucus or pus; from diseases of the throat blocking up the end of the Eustachian tube; and, lastly, from disease of the auditory nerve or of the terminal apparatus connected with it in the membranous labyrinth. *Otitis*, or ear-ache, is an inflammation, usually of a rheumatic nature, of some portion of the external auditory canal. Most frequently occurring in weakly individuals, it causes intense pain, which shoots over the head on the affected side. It may lead to the formation of a small abscess in one of the wax glands found in the passage. Hot applications by fomentations or warm poultices give relief, and if an abcess forms, it ought to be carefully lanced. *Otorrhœa* is a muco-purulent discharge, often of a fœtid odour, from the ears of scrofulous children. It frequently occurs during teething, and it may be one of the sequelæ of scarlet fever, or measles, or small-pox. When pus flows from the ear, it may come from the membrane lining the deeper portion of the external meatus, or from the middle ear by a hole in the membrana tympani, or from diseased portions of bone near the middle, or internal ear. The treatment, of course, varies according to the cause, but generally the discharge may be lessened in quantity, and at all events rendered less offensive, by the use of weak injections of carbolic acid or of Condy's fluid. *Concretions*, consisting of accumulations of wax, often hard and adherent, may block up the external meatus. Frequently these may not impair the sense of hearing, but they give rise to distressing noises of various kinds. They may be got rid by the careful use of injections of soap and hot water. *Polypi*, usually hard and firm, but sometimes soft and gelatinous, occur in the external meatus. The external ear may become hypertrophied, as in idiots; it may contain concretions of urate of soda, as in gout; and it may be the seat of fibrous tumours. In the insane, large tumours, filled with blood, termed *hæmatoma*, sometimes occur. One of the most common causes of deafness in children is chronic enlargement of the tonsils from repeated quinseys or from a strumous habit. Frequently also the Eustachian tube is occluded, but by passing a delicate catheter along the tube, and sometimes by inflating artificially the tympanum with air, hearing may be restored. It is difficult to diagnose, and still more difficult to treat, diseases of the internal ear, in consequence of its delicacy of structure and inaccessible situation. Pathological states of the internal ear may give rise to distressing *entotic* phenomena, such as whizzing, buzzing, hissing, blowing, or clanging sounds; and if they are not relieved by washing out the external ear, or by inflating the middle ear by the Eustachian tube, or by counter-irritation by means of small blisters or the application of tincture of iodine behind the ears, nothing more can be done. (J. G. M.)

EARL (Latin, *comes*; French, *compte*), a title and rank of nobility now the third in the order of the British peerage, and, accordingly, intervening between marquis and viscount. Earl, however, was the highest title and rank of the English nobles *post conquestum* until the year 1337, when by Edward III. the Black Prince was created duke of Cornwall. The "earl" of England was identical with *comte* or *compte* of France; and, so long as Norman-French continued to be spoken in this country, the English "earls" were styled "counts" as well in England as on the Continent. These powerful barons represented and succeeded the Saxon thanes who were *ealdormen*, their own title evidently having been derived from the *jarl* of Scandinavia.

The nature of a modern earldom is readily understood, since it is a rank and dignity of nobility which, while it confers no official power or authority, is inalienable, indivisible, and descends in regular succession to all the male heirs of the body of the grantee until, on their failure, it merges in the Crown. Not so was it with either the nature or the descent of the ancient earldoms of England. In early feudal times titles independent of office did not exist. The earls, or *comites*, of those days, therefore, were actual officers, each having supreme authority in his own earldom, or "county," under the Crown; each one of them also deriving from his earldom a certain fixed revenue, the possession of which was at once an apanage of his official dignity as earl, and the evidence of his lawful and recognized title to it. But an earldom has long ceased to be endowed with any official associations whatever, and has become merely a title by which its owners in male succession inherit and hold the dignity, third in rank, of a peerage. In like manner, the descent and tenure of the ancient earldoms differed in many highly important particulars from the simple succession of the modern dignity. In the course of their chequered history, we find ancient earldoms, instead of passing by a quiet and clearly defined succession from father to son, constantly depending on the rights of female inheritance; they are seen to have been obtained by many a husband *jure uxoris;* they appear to have been transferred in an arbitrary manner, or actually to have been divided between coparceners, or to have been retained for a while by the Crown and let out to farm. At the same time, under such strange conditions as these, and amidst conflicting vicissitudes, until they finally merged in the Crown, the ancient earldoms retained their vitality. They might descend very irregularly, and become vested in successive families, but still they did not become extinct; nor were the claims of legal inheritance wholly forgotten or superseded; and, even if for a time they had been latent or had actually been superseded, they emerged under more favourable circumstances, and under fresh arrangements or modifications they were again recognized by the Crown.

An earl is "Right Honourable," and is styled "My Lord." His eldest son bears his father's "second title," and therefore, that second title being in most cases a viscounty, he generally is styled "Viscount;" under all circumstances, however, the eldest son of an earl takes precedence immediately after the viscounts. The younger sons of earls are "Honourable," but all their daughters are "Ladies." In formal documents and instruments, the sovereign, when addressing or making mention of any peer of the degree of an earl, usually designates him "trusty and well-beloved cousin,"—a form of appellation first adopted by Henry IV., who either by descent or alliance was actually related to every earl and duke in the realm. The wife of an earl is a countess; she is "Right Honourable," and is styled "My Lady."

The coronet of an earl has, rising from a golden circlet, eight lofty rays of gold, each of which upon its point supports a large pearl; also, between each pair of rays, at their bases, there is a golden conventional leaf, the stalks of all these leaves being connected with the rays and with each other so as to form a continuous wreath. In representations, five of the elevated rays with their pearls and four of the leaves are shown. The cap and lining of the coronet, if worn or represented, are the same as those of the ducal coronet. An earl's coronet without cap or lining is represented in the annexed figure.

Earl's Coronet.

In the monumental effigies of noble personages, which yet remain from the Middle Ages, there are many highly interesting representations of the varieties of coronets worn by the earls of those days and by their countesses, before this coronet had assumed its present fixed and definite character. Thus, early in the 15th century, effigies of an earl and countess of Arundel, at Arundel, have very rich coronets. The earl's has a series of leaves and of clusters of three small balls or pearls alternating, all of them being raised to a considerable height above the circlet, the clusters rising rather higher than the leaves. The coronet of the countess differs in having the raised clusters set alternately with single balls or pearls that are less elevated.[1]

The coronet of a countess now in all respects is the same as that of an earl. The scarlet parliamentary robe of an earl has three doublings of ermine. The duke of Norfolk, who is premier duke, as earl of Arundel, Surrey, and Norfolk, is premier earl of England; also he holds his earldom of Arundel, a feudal dignity (as it was adjudged by

[1] In his effigy at Warwick, 1439, the crest of Richard Beauchamp, earl of Warwick, rises from a plain circlet that is surmounted by a series of pearls slightly raised, but without any leaves. Still later in the century, 1483, Isabel Plantagenet, countess of Essex, in her brass at Little Easton in Essex, has a series of leaves, no less than thirteen in number, that rise to a uniform slight elevation above the front of an ample coronet; and about the same time, 1487, the coronets of another earl and countess of Arundel have their circlets heightened with an uninterrupted series of architectural conventional leaves, and once more, at Hever, in Kent, the brass to Sir T. Boleyn, K.G., earl of Wiltshire and Ormonde, represents the maternal grandfather of Queen Elizabeth, with the insignia of the Garter, and wearing a rich coronet, the circlet of which is set with small pearls in contact, not raised, and so numerous that upwards of twenty are displayed.