THE CHORDA TYMPANI

By OLIVER GRAY (Haslemere)

My interest in the chorda tympani, which is the nerve of taste, arose from a chance finding that its intratympanic course varied in different mammals. It was sufficiently arresting to discover, in the ruminants (ox, sheep, etc.), that the nerve passed *below* the insertion of the tendon of the tensor tympani muscle (Fig. 1), where it is attached to the malleus,

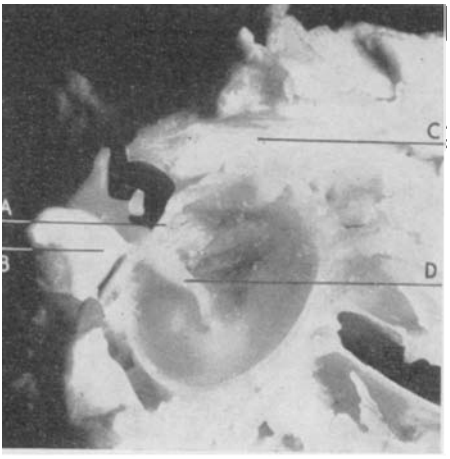


Fig. 1. ×5

Outer wall of the tympanic cavity of the *ox*. Note the chorda tympani passing *below* the insertion of the tendon of the tensor tympani. Prepared and photographed by the author.

A. Chorda tympani
B. Tensor tympani
C. Eustachian tube
D. Manubrium

whereas, as is well known, in man (Fig. 2) it passes *above*. It seemed a little startling to find that a nerve could, during the course of evolution, skip about with impunity, and without offending the preordained pattern upon which anatomical structure appears to have been so meticulously constructed. One felt that this was not quite according to the laws of the Medes and Persians. Further investigation revealed that in the cat and the dog, the hare and the rabbit, and in the hedgehog, the chorda tympani passed *below* the tendon of the muscle, as it did in the ox and sheep, whilst in the Rhesus monkey it passed *above* this insertion which, incidentally, in

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this creature lies somewhat lower down on the manubrium than in man. I came to the conclusion that the explanation of the enigma lay in the fact that, in the primitive state of affairs, the nerve must have existed within a mass of muscle and tendon, and that, in the old world monkeys, the lower fibres disappeared, whilst in the members of the other orders the reverse took place. This obvious deduction, now, does not satisfy me. Within the different classes, and even within the orders, the chorda tympani weaves its way, now on this side, now on the other side of structures as stable as the Rock of Gibraltar. In other words, the nerve itself is indictable for the offences of loitering and trespass.

Although I have myself pursued the matter further, and in a few

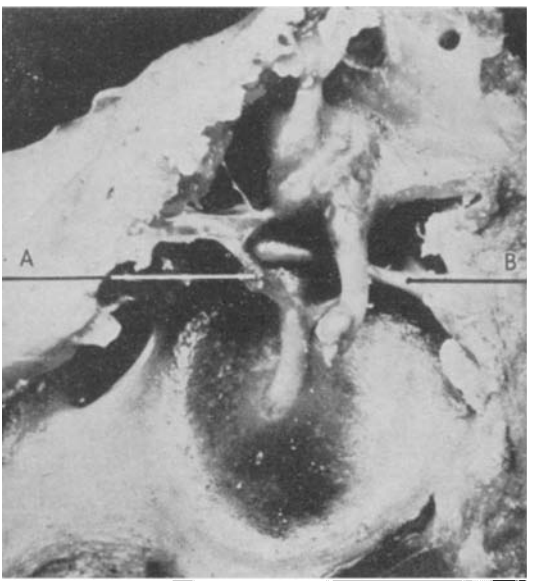


FIG. 2. ×5

Photograph of the outer wall of the tympanic cavity in *man* (reproduced from the *Atlas of Otology*, by the late Dr. A. A. Gray) showing the chorda tympani passing *above* the insertion of the tendon of the tensor tympani muscle.

A. Tensor tympani B. Chorda tympani

instances have found myself differing from the descriptions given by others, this article is based very largely upon reference to the records of those who have worked in this field. I believe, on the other hand, that no one as yet has written on the subject as a whole, and for this reason the monograph may prove of interest. The chorda tympani is always relatively tiny, and difficult to trace. In the mammal we know that it receives the sensation of taste from the anterior part of the tongue, and that, through it, motor impulses pass to the submaxillary and sublingual glands, and also to the stapedius muscle.

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Little is known for certain, about taste in fishes, but it seems probable that it occurs in special buds extensively scattered over the surface of the body in some species. These end chemo-receptors send their impulses to the brain direct through the cranial nerves. The tongue, so called, is probably homologous with the structure found in the higher classes, although it is immobile and has no musculature. Receptors for taste, it can be assumed, exist on the tongue-like platform which lies on the floor of the mouth in the class pisces. Likewise in amphibians, reptiles, and in birds, it is probable that taste is developed, although nothing is really known in regard to this matter, and in birds, if it does occur, it is said to be poor.

In the *fishes* the facial nerve issues from the cranium through the hiatus facialis and, after passing lateral to the hyomandibular component, divides into two branches, the ramus hyoideus facialis and the ramus mandibularis internus facialis. The latter, in the selachii (skates and dogfish) passes medial to Meckel's cartilage, to reach the buccal mucous membrane. In the teleosts, as typified in the cod (Gadus), it crosses lateral to the symplectic and medial to the quadrate, to reach the same destination. This internal mandibular branch of the facial is the homologue of the chorda tympani. In its subsequent history it is usually given off from the facial nerve behind the processus dorsalis, which bridges the columella to the laterohyal, and runs forwards over the columella, to reach the medial side of Meckel's cartilage or the submammalian mandible. To this, however, there are exceptions.

The popular concept of the origin of the auditory ossicles is based upon the conclusions put forward by Reichert, namely, that the mammalian stapes arose from the inner end of the reptilian columella, that the incus derived from the quadrate, and the malleus from the articular. Although it has been challenged, there is general agreement that the columellae of the amphibian, the reptile and the bird are homologous, and their similarity makes this assumption reasonable. In support of these views, amongst other things, it has been pointed out that with its tensor tympani supplied by the trigeminal nerve, the malleus must be, segmentally, some distance from the stapes with its stapedius muscle innervated by the facial. Another point brought forward in substantiation was the relationship of the middle-ear structures to the chorda tympani. There is certainly a deal to be said for the former standpoint, but, as will be seen, the chorda tympani has such a "wanderlust", it is more than doubtful if any reliance can be placed upon the fact that it may lie here or there in the different orders, for even within these there is a most surprising variability.

Amphibians. According to Goodrich, De Beer, Gaupp and others, in the order Anura (frogs and toads), both the facial nerve and the chorda tympani pass down behind the tympanum. The chorda tympani in Rana (frog) now turns abruptly forwards *ventral* to the columella. To make

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confusion worse confounded, the facial nerve, in amblystoma, passes *above* these structures. In necturus the facial nerve splits to enclose the columella. Amblystoma and necturus are, of course, members of the order Urodela (newts and salamanders). In *all* amphibians, however, the chorda tympani travels *below* the columella.

In *reptiles* and in *birds* the facial nerve passes backwards above the oval window and the stapedial end of the columella. The chorda tympani, leaving the facial in its post-tympanic course, arches forwards *above* the extra-stapedial portion of the columella, sometimes known as the hyostapes.

Gaupp tried to explain these paradoxical facts by assuming that the tympanic cavity and its contents were not homologous throughout the tetrapoda—a brave supposition which it is quite impossible to accept; nevertheless it is the only solution which has been put forward in an endeavour to make some sense out of what seems to be nonsense.

The legend continues with a study of the comparative anatomy of the chorda tympani in *mammals*, and again we find this nerve acting in disregard of the rules which seem to govern evolutionary procedure; not once, but on three further counts, is it found guilty of trespass—of behaviour contrary to established custom!

In the majority of mammals the chorda tympani is given off from the facial after the latter has issued from the base of the skull. In these cases it passes forwards lateral to the hyoid cornu; there are, however, exceptions to this, for in the marsupials Didelphys, Dasyurus and Phascolarctus, and in the edentate Manis, it passes medially (Goodrich, quoting Gaupp, Toeplitz, Cords, Esdaile, Klaauw and v. Kampen).

With regard to *marsupials*, in a diagram of the relevant anatomy in Trichosurus vulpecula (one of the phalangers and a diprotodont marsupial) Goodrich depicts the manubrium as part of Meckel's cartilage, and deliberately shows the chorda tympani passing below the tendon of the tensor tympani. By contrast, according to Wassif, in the polyprotodont, Didelphys marsupialis, the chorda tympani passes through a tiny foramen at the base of the anterior process (processus gracilis), which is all that remains to indicate that the manubrium was at one time a part of Meckel's cartilage. According to Klaauw, Phascolarctus cinereus is the only diprotodont known in which the nerve runs medial to the styloid process.

I can find no significant reference to the chorda tympani in the orders Sirenia, Cetacea and Pinnipedia.

Insectivora. In the European hedgehog, the chorda tympani passes through a tiny foramen lying at the base of the anterior process, in a situation slightly below the insertion of the tendon of the tensor muscle. Wassif has found a similar state of affairs in the South Arabian hedgehog, the long-eared hedgehog (in which the foramen is large) and the sacred shrew.

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Rodentia. In the hare, the rabbit and the brown rat the nerve passes below a slender tensor tympani tendon, and in the squirrel it pierces the tendon. According to Wassif, in the greater Egyptian gerbil, a foramen at the base of the anterior process transmits the nerve as in the marsupialia and insectivora.

Ungulata. In the ox and the sheep the chorda tympani passes *below* the insertion of a rather short and fat tensor tympani, with its tendon, and in these large animals it is possible to obtain satisfactory photographs (Fig. 1).

Carnivora. In the dog the chorda tympani enters the tympanic cavity by a little recess which houses the short crus of the incus. Here it lies immediately above and lateral to the pyramidalis tendon. It then crosses the medial aspect of the tympanic membrane *below* the insertion of the tendon of the tensor muscle, the inferior fibres of which bind it closely to

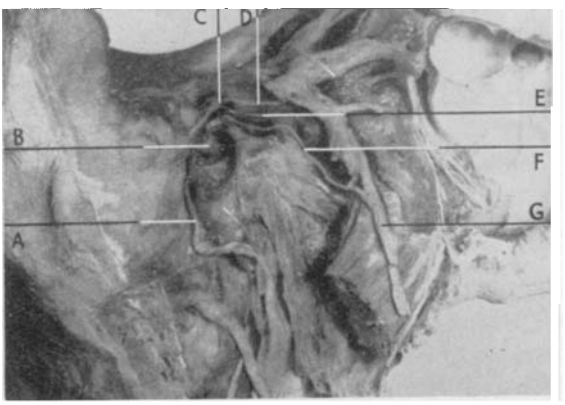


FIG. 3.

Photograph of a dissection in the Royal College of Surgeons, showing the whole course of the chorda tympani and its relationships to other structures.

A. Facial nerve
B. Promontory
C. Geniculate ganglion
D. Greater superficial petrosal nerve
E. Lesser superficial petrosal nerve
F. Chorda tympani nerve
G. Lingual nerve

the manubrium. It now runs a little way along the inferior border of the anterior process of the malleus and then leaves it. The dog has a spacious bulla, and, as in all animals with this feature, the tympanic membrane juts into the tympanic cavity, as it were, on the end of a short pedestal. Surrounding this pedestal there is a deep recess. Into the trough of this little ditch the nerve dips outwards and takes a downward course. Here it gives a branch to the condylar joint. The main branch passes through the thin bone some distance from the petrotympanic fissure, and joins the lingual nerve at an acute angle. In the dissection of a newly born kitten

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the bulla was opened from below and the tympanic cavity split vertically. The tympanic ring was dislodged from the neighbouring bones and, by good fortune, this manœuvre laid bare the course of the chorda tympani as it ran, with little deviation, to its junction with the lingual. The union with the lingual occurs quite superficially below the mucous membrane where it is reflected from the tongue to the lateral wall of the nasopharynx. Further dissection disclosed the branch passing to the submaxillary gland.

Cheiroptera. From the records of Professor Wassif in his recent studies of the bats, the following interesting facts have been extracted. In the Egyptian fruit bat the chorda tympani passes through a foramen just below the insertion of a single tendon of the tensor tympani. In the Theban long-eared bat it passes through the tendon. In the long-tailed bat, Geoffrey's tomb bat and the wrinkled-lipped bat, the tensor tympani has

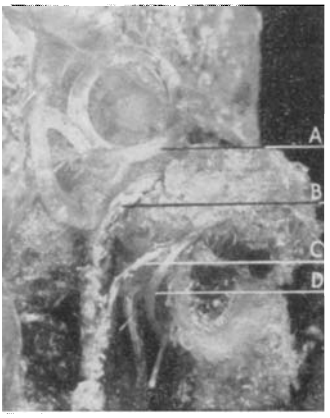


FIG. 4. $\times 4\frac{1}{2}$

Perspex preparation (human) to show the chorda tympani in the first part of its course where it lies in the iter chordae posterius. Prepared and photographed by the author.

A. Lateral semicircular canal
B. Facial canal
C. Iter chordae posterius (chorda tympani)
D. Posterior rim of the tympanic membrane

two distinct muscular bellies, with two tendons separately inserted into the malleus. In all these three the chorda passes between the two tendons.

We come now to a brief review of the chorda tympani in *man* (Figs. 3 and 4). The pathway of the sensation of taste from the anterior two-thirds of the tongue has been the subject of controversy for over a century, and there are more than one hundred references available. Lussana, in 1869, first convincingly described the course of the nerve fibres which conducted these impulses, and his description has been accepted by most, even to this day, viz. *viâ* the chorda tympani to the geniculate ganglion and thence by the intermediate nerve of Wrisberg to the pons. Vlasto (1929) described two cases of known interference with the chorda tympani,

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within the tympanic cavity, in which subsequent section of the submaxillary glands showed histological changes on the affected side, presumed to be due to severence of the nerve. A convincing paper by Lewis and Dandy (1930) concludes, ". . . but one nerve conducts the sensation of taste from the anterior two-thirds of the tongue . . . through the chorda tympani by way of the geniculate ganglion and the nervus intermedius into the pons". Schwartz and Weddell (1938) conclude that the pathway, as suggested by Lussana, is the common one, but that, in certain individuals, the course may pass *viâ* the greater superficial petrosal nerve, for, in one patient, loss of taste followed excision of this nerve, and sensation was preserved in two cases following section of the chorda tympani. Different pathways have been suggested by Schiff, Zeihl and Krause, Harris and many others.

The difficulty of tracing very small nerves in dense bone can be rendered somewhat easier by employing the "Perspex method" devised by the writer, whereby all the soft tissues can be preserved and rigidly maintained in their anatomical relationship, the bone itself being dissolved away by acid. Most of the descriptions here given are classical; but a few details will be found to differ from the orthodox; and, from a study of some forty temporal bones processed in this way, I feel convinced that there is considerable variation in the pattern in which the nerves are distributed, and in the way in which they intercommunicate one with another. Since the pathway of taste may be involved by such anomalous distribution, mention is made of nerve elements indirectly concerned with the chorda tympani.

Just after the mandibular nerve (inferior maxillary) has passed through the foramen ovale, the sensory and motor roots fuse, and at this point the otic ganglion is found on its medial aspect. The otic ganglion supplies the internal pterygoid muscle, the tensor veli palatini and the tensor tympani. Through the lesser superficial petrosal nerve it receives motor fibres from the facial, and sensory fibres from the tympanic branch of the glossopharyngeal. Twigs from the otic ganglion pass to the chorda tympani, to the sympathetic fibres of the middle meningeal artery, and to the auriculotemporal nerve. The chorda tympani joins the lingual, a main branch of the mandibular, at the side of the nasopharynx close to the root of the tongue.

The facial nerve consists of two parts, a motor root, which chiefly supplies the muscles of expression, and a sensory root, known as the intermediate nerve of Wrisberg, which receives the sensation of taste from the anterior part of the tongue through the chorda tympani. The geniculate ganglion lies in the path of the facial nerve at the geniculum. It is the nucleus of the sensory root, and consists of a swelling which has a distinct reddish tinge, which extends some distance along the facial nerve. The peripheral elements of the ganglion comprise two nerves, one which forms

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the greater superficial petrosal and the other the intermediate nerve of Wrisberg, which passes down the facial canal to leave the canal as the chorda tympani. This nerve can be made out as distinct from the facial in the human subject, but in some animals it is very clearly separated, as in the ox. Very soon after the facial nerve has turned abruptly backwards from the geniculum, it gives off a twig. This twig passes forwards and joins the tympanic branch of the glossopharyngeal (Jacobson's nerve) coming up from the promontory. The conjunction of these two occurs on the medial aspect of the canalis musculotubularii, which houses the tensor tympani muscle, and together they constitute the lesser superficial petrosal which travels above the tensor muscle. Eventually this nerve penetrates the bone, reaching the interior of the cranial cavity parallel to the greater superficial petrosal. The twig referred to must be very constant, for I have always found it whenever I have sought it, although it is very tiny. It is not definitely established whether it carries motor or sensory fibres, or both. The greater superficial petrosal nerve arises from the geniculate ganglion, and, early in its course, before it surfaces from the bone at the hiatus of the facial canal, it sometimes receives a branch from the tympanic branch of the glossopharyngeal. This, however, is unusual. Beyond this, and after it escapes from the hiatus, it sends a communicating branch to the lesser superficial petrosal nerve. This branch sometimes comes direct through the bone from the geniculate ganglion. After it has left the canal it also commonly is joined by a branch from the lesser superficial petrosal. The greater superficial petrosal passes beneath the semilunar ganglion and joins the deep petrosal to form the nerve of the pterygoid canal (Vidian). Let us return to the facial nerve; within the facial canal, it gives off the twig to form the lesser superficial petrosal, the nerve to the stapedius muscle and the chorda tympani, and communicates with the auricular branch of the vagus (Arnold's nerve) just above the iter chordae posterius. The chorda tympani in the infant leaves the facial outside the skull, but, in the adult, enters the iter chordae approximately 4 mm. above the stylomastoid foramen. In this channel it runs almost directly upwards and forwards to the outer side of the posterior wall of the tympanum, beside the rim of the tympanic membrane (Fig. 4). Its course can be divided into four, of which this is its first part. In its second portion it crosses the outer wall of the tympanic cavity enveloped in a fold of mucous membrane, passing medially to the manubrium of the malleus and *above* the insertion of the tensor tympani muscle (Fig. 2). Two little recesses are formed by the fold of mucous membrane which encloses the nerve on either side of the manubrium, known as the anterior and posterior folds of Troltsch. The third part lies at the inner extremity of the petrotympanic fissure. "After leaving the tympanic cavity, the chorda tympani runs inwards and forwards through a long fine canal in the bone parallel with, and in front of, the Eustachian tube. It passes

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across the temporo-sphenoidal suture, and continues for a millimetre or two inwards through the sphenoid; it then turns downwards and takes its exit from the base of the skull by a minute foramen behind the base of the spine of the sphenoid bone. In a small number of cases it leaves its bony canal earlier in its course" (A. A. Gray, *Atlas of Otology*) (Fig. 5). In nine cases in which the author was successful in tracing this portion of the

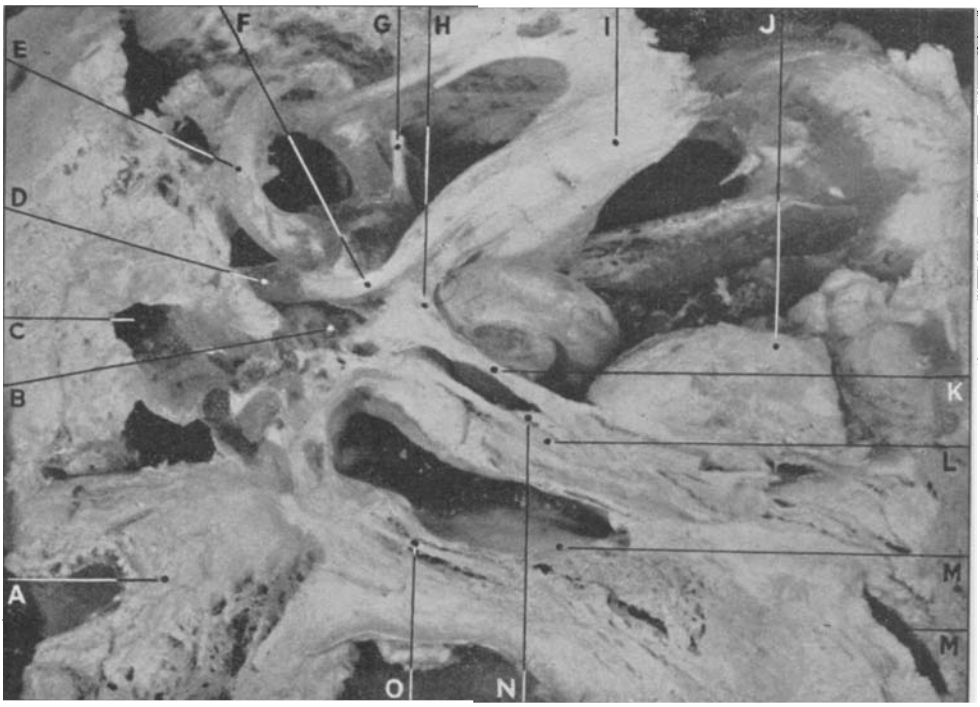


FIG. 5.

Photograph of right labyrinth (human) and related structures in polymerized methyl methacrylate (Perspex) after removal of the dense bone by hydrochloric acid. Viewed from above.

A. External auditory meatus
B. Facial canal
C. Mastoid antrum
D. Lateral canal
E. Superior canal
F. Nerve to superior and lateral ampullae
G. Aqueduct of the vestibule
H. Geniculate ganglion
I. Internal auditory meatus
J. Carotid artery
K. Great superficial petrosal nerve
L. Lesser superficial petrosal nerve
M. Eustachian tube
N. Nerve from tympanic plexus
O. Chorda tympani

chorda tympani, its course corresponded with this description. It must be admitted that in searching for this elusive nerve on six other occasions it was lost sight of, and it may be that in some of these it passed out through the canal of Hugier in accordance with the generally accepted belief. The

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fourth part passes downwards and forwards to join the lingual nerve at an acute angle (Fig. 3).

What I have chosen to describe as the third portion of the chorda tympani should be recognized as the "normal" state of affairs in the adult. The explanation of how it usually comes to lie in bone in this pretympanic region may be that it becomes incorporated in the osseous tissue which spreads in certain regions over the base of the skull as the child gets older. This is, indeed, the way in which the iter chordae posterius comes about, for it does not exist as a channel in the infant skull.

I feel challenged to offer some solution of the mysterious behaviour of the chorda tympani in its evolutionary history. That there is an unsolved mystery has been acknowledged, and the facts, as gathered together in this article, increase rather than diminish the difficulties of the problem and thereby invite speculation. The cranial nerves are numbered according to convention. They do not, of course, represent segments; but they are, anatomically, in sequence, and it is the intrusion of the vestibular and cochlear elements which causes such confusion in the cephalic pattern—a pattern which otherwise is fairly easy to disentangle. Nevertheless, making all allowances for this, how does the chorda tympani start out on its course in association with the VIIth and VIIIth nerves, finally to end up as the travelling companion of the lingual, a branch of the Vth nerve, side by side and within a common sheath? The Xth nerve has been called the vagus—the wanderer. Without let or hindrance it seems to have travelled to most parts of the body, for, in fishes, it extends, by means of the lateral line system, over the head and down to the root of the tail fin. Segments are no barrier to its dominion, for it also holds sway over the function of all the viscera. That the chorda tympani has likewise transgressed cannot be doubted. We do not know how or when this all took place, but the historical events must have been in the nature of actual migrations—extensions of the nerve fibres beyond the boundary of the segment to which they belonged. Having acquired this propensity for invading tissues, which can be looked upon as foreign soil, can we deny to the chorda tympani, as to the vagus, the property of seeking new pathways, at random, during the evolution of the different orders?

Acknowledgments

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