Notes on the Ear

Patrick Farmer


Susana Gómez Larranaga – Ruins in Reverse (from Azimuth, the ecology of an ear)

N.B. I have chosen to omit a number of threads stemming from the electroanatomy of the cochlea, as I will be spending time with them in my forthcoming publication, 'To Suckle a Field of Monsters'

Lately, I've written a number of essays that refer to the anatomy of human ear, so it seems like a good time to try and consolidate some notes I've made over the years, perhaps for no other reason than exfoliating an overly mechanistic layer of my sensibility.

This was my original intent whilst writing *Azimuth*, but the abundance of information there seemed better suited to a poetics. Here I've tried to focus on what we could call a practical nature, at best a brief introduction, though there will surely be occasion to drift, and certainly to return, as the ear is both a good place to sleep, and to leave. I can't imagine many reading this through, but I hope it can provide a frame of reference when needed.

It's obvious I'm not an otologist, or an audiologist, any sort of gist… I'm simply an amateur (with an abandoned amusement park for a right ear) who identifies much too much with Gustav Flaubert's *Bouvard and Pecuchet*. As such, I've done my best to ensure the information here is an accurate measure of myriad collation, my own research, and experience.

Perhaps some will note the absence, or scarcity, of information regarding such things as the temporal bone and auditory bulla. I leave these out purely because if I include them I will then need to include something else and so on. I also haven't included a list of references because said list would be a giant. However, please feel free to get in touch if there's anything specific you'd like to know more about, hopefully I can point in a direction.

It's difficult to avoid generalising, though when I do, it is more for ease of use than anything else, as during such moments it is increasingly apparent I'm not talking about myself (my ear is anything but general), so in essence I could be talking about anyone and any one.

Likewise, devising any semblance of coherent order is essentially an exercise in superficiality and hodology/pathology. It could go any number of ways, especially in mind of the quavering ultrastructures of the labyrinths, liable to flip at any moment, like the Earth's magnetic fields.

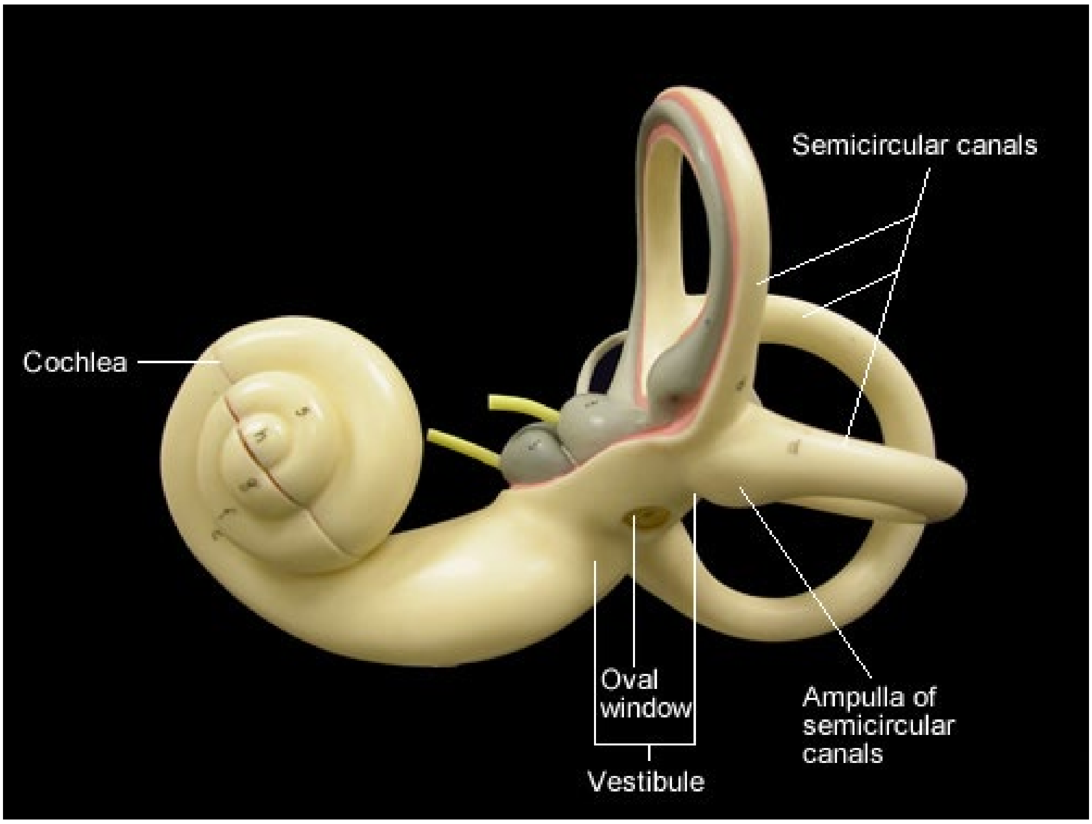
This whole thing is brought to bear in relation to something resembling aural diversity, inasmuch as these notes will not only hear themselves differently, but will change their meaning in accordance the reader. This is closely akin to Felix Guatarri's notion of metaphor as metamorphosis, a displacement that produces a prospective reconfiguration of the sense produced by the symptom between word and person, the word between person and symptom, and so on. Like birds that come and tap at a window.

I feel like I've written with the human ear (from hereon, 'ear' will denote human ear) more times than I can recall, yet every time I do so, it seems I find something I'd previously missed, or I encounter new research that's gleaned its own light. As such, without wishing to repeat myself, please consider this a process.

I've tried many times to open the ear out into a much wider space of ideas, a space not predicated on the vernacular or proteins and voltage. I'm not sure how possible that is, but that's what keeps me coming back, what enables me to sleep in the ear is the simple fact that there's still so much to learn (to remember that I've already forgotten) about its micro and macro molecular natures and substructures, molecular warp and woof.

By 'opening' the ear, I'm referring to its many lives (certainly not just human)… electric and magnetic, its noise, its gravitation, sound, heat and light… its innumerable chemical signals, its energy! Amidst this sweating feedback loop that drops its own boundaries I think we can also include affect, emotion, what else… all sorts of pullulating myths as they metamorphose in such densely spectral labyrinths, guided by slipping in and out of morphic wholeness, where one thing is always on its way to becoming another. The faster such forces follow one another the more coherent a continuum they form as they in turn move further apart.

An ear is immanent and innumerable, one might be abandoned, one might catch fire, another might be carried way by the wind, another might vent like a spleen. Perhaps it's easier to speak about phases and maturations, rather than endings and fructifications.



The auricle, ('outer' ear) is quite unique in its morphology, inasmuch as it acts as a mirror for what it makes sound appear to be. Sound created the ear in order to hear itself, that old adage. The terms that populate its surface, helix, tragus, concha, form its venation.

The auricle twists and folds in such a way that it enhances sound within seams typical of the human voice (much like the tectorial membrane). Its shape is such that it can amplify vibrations up to 100 times. Vibrations from 'front' and 'sides' are enhanced in this way, those circling from the back are reduced, creating small differences in volume and a tendency for the rest of the body to participate in its own asymmetrical spectral reflection.

Auricle means 'ear shaped', it's curious to think that the outer ear is called an auricle because the outer ear looks like an outer ear. Auricle can also be referred to as pinna, Latin for wing. Pinna appears in botany as the primary segment of a compound leaf, as a genus of bivalve molluscs known as pen-shells, and in zoology as a feather or fin. Auricle comes from the word auditory, which itself relates to the medieval ritual of confession. So here language and experience are reversed, creating a kind of wild logos, a transmission that is also a reception.

We listen to the oracle we confess to the auricle, and so auditory, derives from auricularis, which is the term for any of the three muscles, a triangle attaching the cartilage of the external ear to the skull. Auricular simply means anything relating to the ear, or hearing. It's as if, by tracing these vagaries and disturbed certainties, the evolution of a word is akin to a sound wave mapping and expanding its own self-similarity.

The ear canal (auditory canal / external auditory meatus) consists primarily of bone, fibre, and cartilage. It is self cleaning, if we consider that cerumen is part of its anatomy, as it is part of the cerumen's, and generally speaking it is around 2.5cm long, 0.7 in diameter. There is usually a slight curve in the tube, which extends from the the pinna to arrive and depart at the tympanic membrane.

The tympanic membrane (tympanum / ear drum) is a thin and oscillating transparent partition of nonglandular skin that separates and links the auditory canal from the depths of the middle ear cavity. As such, it both receives and transmits environmental vibration, from where we happen to be to the excitations of ossicles.

It is stretched obliquely (slanting) from above to below (I hope it goes without saying that such attempts at orientation are relative), from outside to inside, and from the back to the front. Therefore it is not perpendicular to the axis of the canal itself.

One of the effects of the tympanic membrane's obliqueness is an increase in the surface of impression and the capacity of vibration (ossicles amplifying sound by a factor of three, primarily due to the fact that when sound comes into contact with liquid, like the atmosphere of the inner ear, a great deal of it is dispersed, so the ossicles and tympanic membrane overcome what's known as the impedance between air and fluid–the ossicles act in a similar fashion, providing just the kind of coupling required for the transmission of vibration in the floating world of the inner labyrinth). Indeed, it has been thought that precision of hearing is in direct proportion to the obliqueness of the tympanum.

The membrane has three layers, the outer – part of the skin of the ear canal, the inner – part of the mucous membrane lining the middle ear, and in between there is a layer of radial and circular fibres that stiffen and tense the proportions of the disc. As such, it is somewhat vulnerable and sensitive to pain.

The membrane has been subject to an oh so common designation of proximity, apparently it measures a difference in relation to what is 'proper' to oneself and what is the realm of the other. I would rather concentrate on its vocabulary, as the disc is home to such terms as 'umbo', the most depressed point, which, put simply, corresponds to the malleus (an ossicle), and 'cone of light', which acts as a guide upon closer audiological inspection.

Anatomically speaking, it's the Eustachian tube that is, in its own way, responsible for the aforementioned proximity. It corresponds with and connects the middle ear to the back of the throat along what we might call increments. Enabling air pressure (and draining fluid) to equalise on both sides of the film of the tympanic membrane.

The air in the middle ear is not in 'direct' contact with the atmosphere outside the body, and so the Eustachian tube is a link to other mediums via the creation of pressure differentials. When we chew, yawn, and swallow, the tube opens, otherwise it tends to remain closed. In other words, when we yawn we're hearing the tube open.

In 1546 Giovanni Filippo Ingrassia, professor of anatomy at the University of Naples (a then burgeoning city with roughly nine times the population of Marseille, its marketplaces brimming with taffetas, silken knots and cockades, a silken air promising freedom, but not necessarily a full stomach), identified a third small bone in the middle ear, an ossified ring he named stapes:

"By chance, while showing students the two small bones of the middle ear, the malleus and the incus, I noticed that a third bone had fallen on the dissecting table, and for its similarity to a bracket or to the Greek letter Delta, I thought to call it 'stapes' or 'deltoid.''

Ingrassia was called a 'scholar of the human body', he lectured on medicinal theory and practise, on Avicenna and al-Razi. Possessing a rare osteo-sensibility, he gained even greater renown upon declaring that Galen, the famous philosopher-surgeon of Ancient Rome, had often described monkey bones when writing about those of a human. He intuited the symbolic wildness and undertextures of the inner ear's oval and round windows, hypothesised on the vibratory capacity of teeth, opined the extra-sensorial conduction of bones.

The ossicles (malleus/incus/stapes) are the smallest bones in the body, and evolved from the lower jawbone of amniotes. They transduce vibration from one medium to another, and, suspended by ligaments, form a path from ear to ear. When arranged together, the ossicles look like a rhizome of ginger, and move like a moorhen washing in muddy water.

The malleus (hammer) lifts from the tympanic membrane within the cavern of the middle ear. Its attached to the incus (anvil). The malleus has a neck and evolved from vertebrates that laid their eggs on land. The handle of the malleus is sometimes noted as a reddish-yellow streak. If we traverse the bone as a whole, or part of the ossicular line, we note that its extreme end, in the sense of its infinitesimal nature, is a little white and rounded prominence.

The middle ear once had a function in support of the jaw. The malleus sprouted from the jaw joint and remained attached for the first half of mammalian evolution. It now has a long arm, a bony wing. The incus receives lateral vibration from the malleus, which it then transmits to the stapes (stirrup).

The ossicles are a distortion of many bodies, many environments, the stapes wants to break a window (see below) that wants to be broken, yet it cannot, because it's the smallest and lightest bone in the body.

Middle ear responses are influenced by the ability of the inner ear to process the frequencies being transmitted. Where the ossicles are called a chain, it seems fit to call them a line. In most therian mammals the middle ear is encased in a bony structure called the auditory bulla, a dark space, the floor of the middle ear cavity. This protects middle ear tissue–it is also a genus of hermaphrodite sea snails, and is Spanish for noise.

The oval window is a reniform (kidney-shaped) membrane, a covered aperture through which vibrations travel from the ossicular pivot of the middle ear, it is yet another intersection in an ear seemingly made up of nothing but.

It's quite difficult to write about, or maybe I should say to describe the location of, any one part of the cochlea without then needing to refer to others, and to others in turn. At this point, the depth of detail is essentially limitless, and orientation becomes increasingly difficult. When I read about the anatomy of the inner ear and auditory pathways the only way I can really engage is to imagine I'm a reading a science fiction story.

The ear is a fractal organ. To look into the labyrinths is a journey of the imagination, to enter into an archaic revival, which is not to say, going back to someplace or somewhere, not a return to, but a return of. In the spiral of the cochlea is the cosmos.

The cochlea is a fluid filled spiral within a fluid filled spiral that never really looks like a spiral because its edges are always in motion. It spans roughly two and a half revolutions in humans, which corresponds to a frequency spectrum, and is otherwise known as the auditory (osseus) labyrinth (within which we find the membranous labyrinth). This is a thing with the cochlea, there are a lot of names, and those names also have other names, I'm going to try and stick to just one set of them.

As air pressure fluctuations and all they contain pass through the cochlea (what's initially known as the vestibular duct), the stapes causes the oval window to compress, which in turn, at the other end of the cochlea (tympanic duct), causes the round window to move in the other direction, and this obviously works both ways in compression (causing an increase in local cochlear pressure) and rarefaction (causing a decrease). The main reason for this is to create a fluid pressure equilibrium.

This stimulation can happen also via direct vibration of the cochlea from the skull. The latter is referred to as bone conduction hearing, as complementary (or not) to air conduction hearing. Both AC and BC stimulate the basilar membrane of the cochlea in the same way. At this point it's worth noting that the basilar membrane moves in accord with longitudinal wave patterns, so with compression and rarefaction, whilst the tectorial membrane (I'll go into more detail about these membranes below) can move as a transverse wave, with crests and troughs. This is of particular interest when we note that longitudinal wave forms are traditionally associated with sound, and transverse with electromagnetism, of light. A recent experiment out of City university in Hong Kong has shown however, that sound can behave like a transverse wave. I bring this up because I think it highlights an alchemical possibility, that by a shift in perspective, the apparent opposite of something may come into focus at any moment. Many science fiction writers, notably Alice Bradley Sheldon, otherwise known as James Tiptree Jr. pre-empted such findings by referring to such phenomena as light-sound, most notably in her book, *Up the Walls of the World*, published in 1978.

Just to recap. Waves of metamorphosing pressure come through the oval window into the vestibular duct, pass around the spiral to the apex of the osseous labyrinth, through what's called the helicotrema and into the tympanic duct, which leads to the round window. This is a continuous passage of fluid and pressure.

Both the vestibular and tympanic ducts of the osseous labyrinth are full of perilymph, which is essentially a conductive fluid. In the middle of these ducts is another spiral, called the cochlear duct, this gets a little complicated when we realise that the apex of the cochlear duct is at the base of the ossues cochlea. The cochlear duct is full of endolymph, a unique conductive fluid rich in potassium.

What's currently known as tonotopy (tonos – tone / topos – place) is the mapping of different frequencies along the length of the cochlea, a really beguiling and wondrous thing. It was 'discovered' by George von Békésy in the mid 20th century, so it's a recent thing and the implications are very much still in their infancy. Tonotopy is thought to begin at the cochlea, which then spreads throughout the brain, though I think it'll be observed to exist through the body, and indeed, why stop there…

When we learn about the tonotopic life of the inner ear, and the brain, the notion of tuning the ear branches out into many other dimensions. The highest frequency sounds are distributed among the base of the cochlea, and the lowest at the apex, so again, it's kind of the opposite way around to what you'd think… but this has to do, at least in part, with the inverted relationship of the three ducts.

I should at least briefly mention the cochlear amplifier, which increases the deflection of the membranes in the cochlear duct, but also augments the resolution that we can detect between two different frequencies. So essentially, fluctuations that come in at 1000hz will be amplified at one part of the spiral, and those of 1005hz at another, this enables the afferent and efferent motion of signals along the auditory radiation pathways of the brain.

The cochlear duct contains the sensory region of the cochlea, otherwise known as the organ of Corti. The organ of Corti lies on the basilar membrane at the base of the cochlear duct. Under the organ of Corti is the tympanic duct and above it, the vestibular duct. It borders the central bone of the cochlea, otherwise known as the modiolus, and the outside wall of the cochlea, which contains a tissue called the stria vascularis, a very particular place that pumps out endolymph. Here we recall that outside the cochlear duct the other two ducts (vestibular and tympanic) are bathed in perilymph, an extracellular fluid.

The stria vascularis also serves as a battery, it charges the endolymph, and this is called endocochlear potential, which is the charge, around +80mv, that enables hair cells to respond to 'environmental' stimuli.

The basilar membrane separates the tympanic and cochlear ducts (segregating endolymph and perilymph, though it's permeable to perilymph), undulating in response to pressure waves. It varies in width, stiffness and mass along its length. It's widest and least stiff at the apex of the cochlea, and subsequently stiff and narrow at the base. As we've said, high frequencies localise near the base, and low near the apex. Reissner's membrane separates the cochlear duct from the vestibular duct, helping to transmit vibrations and nutrients in between the two.

The cochlear duct is evidently inside the cochlea, and inside the cochlear duct, is the organ of Corti, and inside said organ, are hair-like cells, sensory cells that release information onto what's known as spiral ganglion cells. In the cochlear duct there are both inner and outer hair-like cells, the inner hair (I'll stop saying -like now) cells are the only ones that send messages to the central nervous system, and the outer hair cells in fact receive messages from the brain. The outer hair cells are in essence, the cochlear amplifier, the physical substrate that enables us to, well, as the name says, amplify sounds in the cochlea.

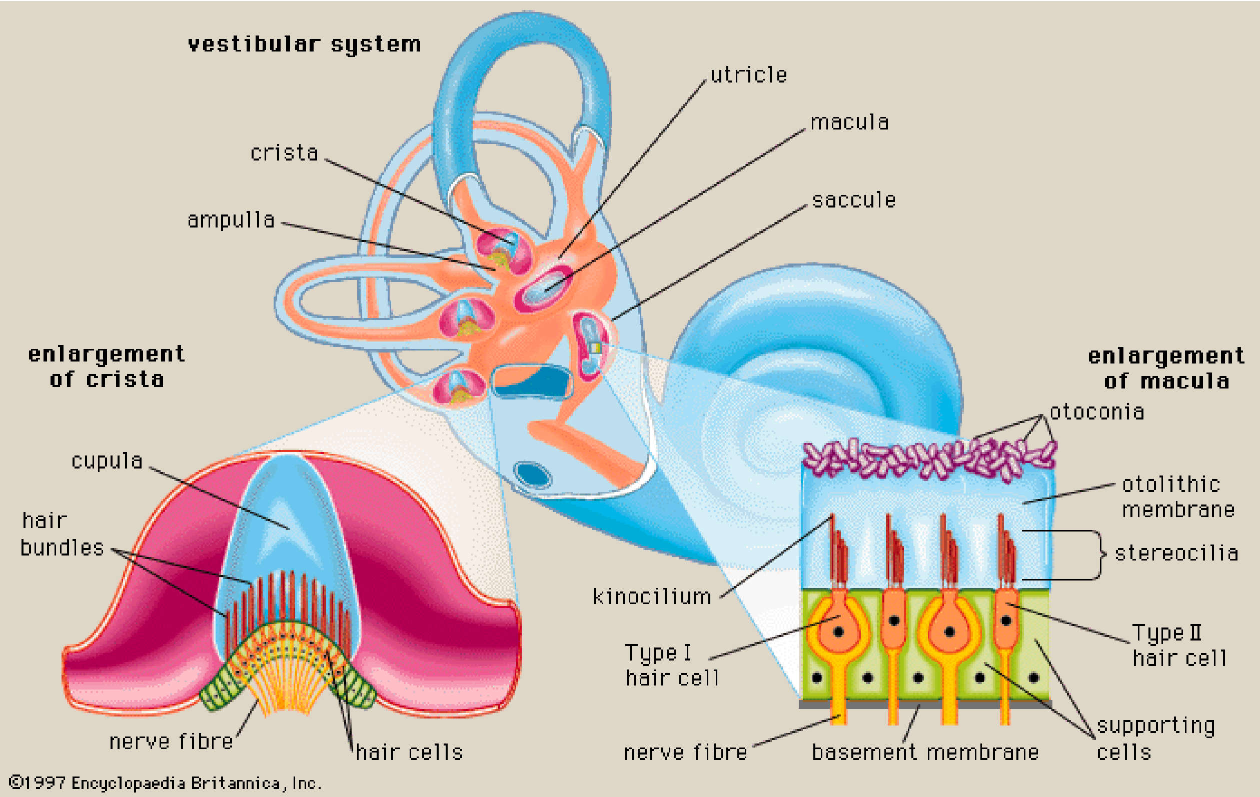
All the hair cells have a cell body, and then a bunch of hair-looking things, which are not hair at all, but what's called *actin*, these are formed as bundles, and the outer hair cells (of which there are approximately three times as many compared to inner hair cells) are embedded into the tectorial membrane (rather than plumb the depths of said membrane here, I feel it's best to link to another essay of mine called Soft Doors), which is made of molecules called tectorin, and the inner bundles are free to move within the endolymph of the organ of corti, and they of course move in a manner similar to the oval and round windows.

If we try and map out the singular anatomy of these interconnected cells, there would a cell body and stereocilia, which are joined by proteinaceous tiplinks, so they join taller stereocilia to smaller, wherein the tiplinks end and are physically attached to what's known as the met channel. So when the bundle is moved the door, if you like, opens, and ions can flow through said channel. The driving force along the met channel goes from +80mv on the endolymph side to around -50 mv on the internal side. So hair cells have an elevated resting potential. The driving force is >100mv and that's in stark contrast to the typical force which is around 70mv. So once the lid of the tip link comes off and the channel is open, potassium, sodium and calcium all flow through the cation channel, resulting in quick (about 20khz) responses.

The outer hair cells, embedded in the tectorial membrane, amplify the signal for the inner hair cells, which are bathed in endolymph. They do this using a molecule called prestin. Prestin is a molecular motor, a molecule that changes its confirmation in response to voltage, which shortens and lengthens the length of the cell. As waves of pressure pass through the cochlea, the bundles of outer hair cells go back and forth in accord to the compression and rarefaction of the windows, causing the prestin molecules along the hair cell to lengthen and shorten, which has a direct effect on the inner hair cells, creating a stimulus. So if there is no outer hair cell function, no prestin function, there is no hearing, as we understand it.

Békésy thought tonotopy was the wave theory par excellence, the one that 'explained' hearing, and yet now we have the presence of the cochlear amplifier integrating into this particular vision, and on and on we shall go, continually breaking the ear into pieces over and over and over again until eventually it becomes so small that the whole reveals itself.

Imagine all the parts of the ear working in unison, from the ripples and waves of the conductive fluids to the vibrations in the bone to the hair cells flowing back and forth, it's endless.



The human inner ear is a place of co-habitation, home to both the cochlea, and the vestibulum. Whilst the hearing and balance organs are linked, vibration should 'never' make fluid move in the latter. A duct channels acoustic pressure changes away from the balance organs, so they can, for instance, send messages to the brain cocerning the position of the head in relation to the earth's gravitational fields.

The balance organs of the inner ear, which make up the vestibular labyrinth, are made up of three semicircular canals and the vestibule, which consists of two otolith organs, the utricle (closer to the semicircular canals) and saccule (closer to the cochlea). Angular acceleration is sensed by the latter, static head position, in relation to the planet's gravitational fields, and linear acceleration by the former.

Semicircular canals are balance organs, and balance is a sense. The canals are tilt and gravity sensors that each correspond to a plane in which the head, and indeed the body, can rotate. There are the anterior (sometimes called superior), posterior and horizontal semicircular canals. These are all essentially concerned with rotational equilibrium.

The saccule and utricle are thin-walled membranous sacs, they each contain what's known as a neuroepithelium, made up of sensory and supporting cells, aggregated in a macula. The macula of the utricle is in a horizontal positon and in the saccule, a vertical position. Each cell contains stereocilia, a tuft of 'hairlike' processes, which project toward a sheet of gelatinous material, covering the entire surface of the macular. This surface is in turn covered by a mass of infinitesimal calcium carbonate crystals called otoconia, which collectively constitute the otoliths. In the semicircular canals there is what's called the crista, which contains the cupula. As stated, each of the otolith organs contain a macula, full of otoconial crystals. We'll go further into all this.

The otoconial layer, when loose, or unfixed, has the consistency of lightly packed sand, which helps to project a steady stream of impulses around the brain, even when the head is at rest. When the head moves, however slightly, the layers shift in seams of minute displacement, deforming the stereocilia, thus modulating neural messages.

Saccular crystals are fairly constant in size and uniform in shape, whereas utricular otoconia tend to be smaller and vary widely in shape, between rhombohedral and cylindrical. I would place the otoconia in the micromolecular structure of a blade of straw, a fractal distillate of time, a continuous turnover of calcium between the otoconia and the body calcium stores.

The crystals are not embedded in the gelatinous portion of the membrane, only loosely bound by small amounts of matrix material, a surface of millions of small crystals and chemical interactions, so it's possible for crystals to become dislodged, and drift.

A physiological mechanism exists in the utricle for removal of dislodged otoconia. Crystals can come into contact with the so-called dark cells of the utricular wall which appear capable of dissolving displaced otoconia.

The frequencies of the vestibular labyrinth are wildly different to those of the auditory labyrinth. With human hearing, we're of course dealing with a rough peak of 20khz. In the vestibular system however, most of the stimulation is below 10hz, with head movements whilst walking being around 2-3hz.

As already stated, inside the osseous labyrinth is the membranous labyrinth, and between the two is a fluid called perilymph, a conduction fluid. The close anatomical proximity of balance and auditory organs in the human body has led to a number of means by which acoustic pressure changes are funnelled away from the vestibular organs. The perilympthatic duct is one (where the perilymphathic space is connected to the subarachnoid space), the differing resonant frequencies of the vestibular and auditory labyrinths, another.

The otolith organs of the inner ear have been called those organs through which gravity speaks, and it's in the inner labyrinth, along that strange border between vestibular and auditory life, where the fluid and pervasive influence of gravity is perhaps most keenly felt.

Angular acceleration (how much something spins, rotates, turns), is primarily the role of the semicircular canals, in other words rotational equilibrium. Linear acceleration (which is as it sounds, acceleration along a straight line) is the one of the role of the otolith organs.

As already stated, at one end of each of the three canals there is what's known as a crista, which is where the hair cells are concentrated, all oriented in one direction, embedded in a gelatinous veil, called the cupula. There are three corresponding movements–yaw, pitch and roll–and these correspond not to a single canal, but register as a mixture.

A yaw movement is a rotation in the transverse plane, equivalent to the horizontal canal, a side to side rotation of the head, as though indicating 'no'. As I practise this, the fluid in the membranous labyrinth (which is fixed to the head) moves relative to the head, creating a drag on the cupula.

What this means is that if I move my head in one direction, the relative movement of the endolymph is in the opposite direction. If I'm moving my head to the right, the endolymph in the right ear excites the hair cells, which is the equivalent of depolarisation. So each of the canals are paired, whatever happens in the one, will counter its opposite in the other.

If I move my head a half pitch forward and a half roll right, that'll make fluid in the right anterior canal move away from the utricle, so it'll move in the opposite direction of the movement of the head. The hair cells are oriented away from the utricle, so whilst I move my head one way, the fluid moves the other way, and this excites the hair cells, it depolarises them. Subsequently the hair cells in left side of the posterior canal, will be inhibited, they'll be hyperpolarised.

Virtually all movements are combinations, additions of at least two different vestibular stimuli, including those that require the saccule and utricle. When a person drinks a large amount of alcohol, the specific gravity of blood goes down, the cupula gets a blood supply, so very quickly after one drinks this alcohol, and the blood is thin, the cupula will also have a decrease in its specific gravity, and will therefore float up, within whatever canal it is. The result of this is an excitation in both the horizontal canals, in pairs that aren't usually excited together, because if one horizontal canal is depolarised, this produces an opposite state of hyperpolarisation in the other. The dual excitation of both, in this example, the horizontal canals, usually produces an experience of vertigo and nausea, which is the bodies way of attempting to rid itself of a toxin.

Just as the canals detect angular acceleration, the saccule and utricle detect linear acceleration. The first difference is that the hair cells here are embedded into a rock, not a cupula, which makes sense, as if we want to measure gravity, we don't use a feather, a stone seems more apt, something that gravity can act on. A mass is needed.

This rock is what's known as an otoconial mass, made out of otoconin, a protein, with calcium carbonate, held together with a gel containing various proteins made during embryogenesis. So essentially the otoconial mass we have at birth is the one we have throughout a life.

The otoconial mass weighs something, a substantial mass that gravity can operate on. In many ways the crystals of the inner ear symbolically represent the outer world, moving with it in conjunctions of opposites, a motion that certain psychologists believe provide the first physical experience, the gravity stage, from which many subsequent mental introjects derive their quality.

Let's say that I jump up and down, as I go up gravity is acting more upon me, displacing the rock, the otoconial mass, downwards, and so when I come back down, the mass floats back up, and I have a moment of weightlessness, outside of gravity. This feeling comes from the floating up of the otoconial mass.

For some a tiny piece of the otoconial mass can become dislodged, and it'll float around the vestibulum, eventually ending up in the lowest point, which is the posterior canal. Because gravity is operating on us all the time, we are able to not only detect translational movement, or acceleration, but static head tilt. If I tilt my head to the left I'm getting a vestibular message. As I do this it effects both the otolith organs, but mainly, in this sense, the utricle, due to the fact that my head is no longer horizontal, thus displacing the otoconial mass, and creating a response. In the same way, if I move forward, the otoconial mass is displaced backward.

Otoconia have been called, grains, stones, and crystals, every single crystal in the inner ear is in fact multiple crystals, composed of organic and inorganic compounds. The otolith crystals exist in a state of dynamic equilibrium with their fluid environment, incipiently registering the effects of gravity upon the brain.

The otoconial mass does not transform into a finished state that would remain unaltered throughout a life, but churn their own flux within the wider labyrinth, wherein every detail of their structure works to accommodate the existence of the life of audition. Otoconia are said to mark a threshold of human identity, across which pass the processes that enable us to have our being. It's possible to determine the age of a fish by 'reading' the otoconial rings.

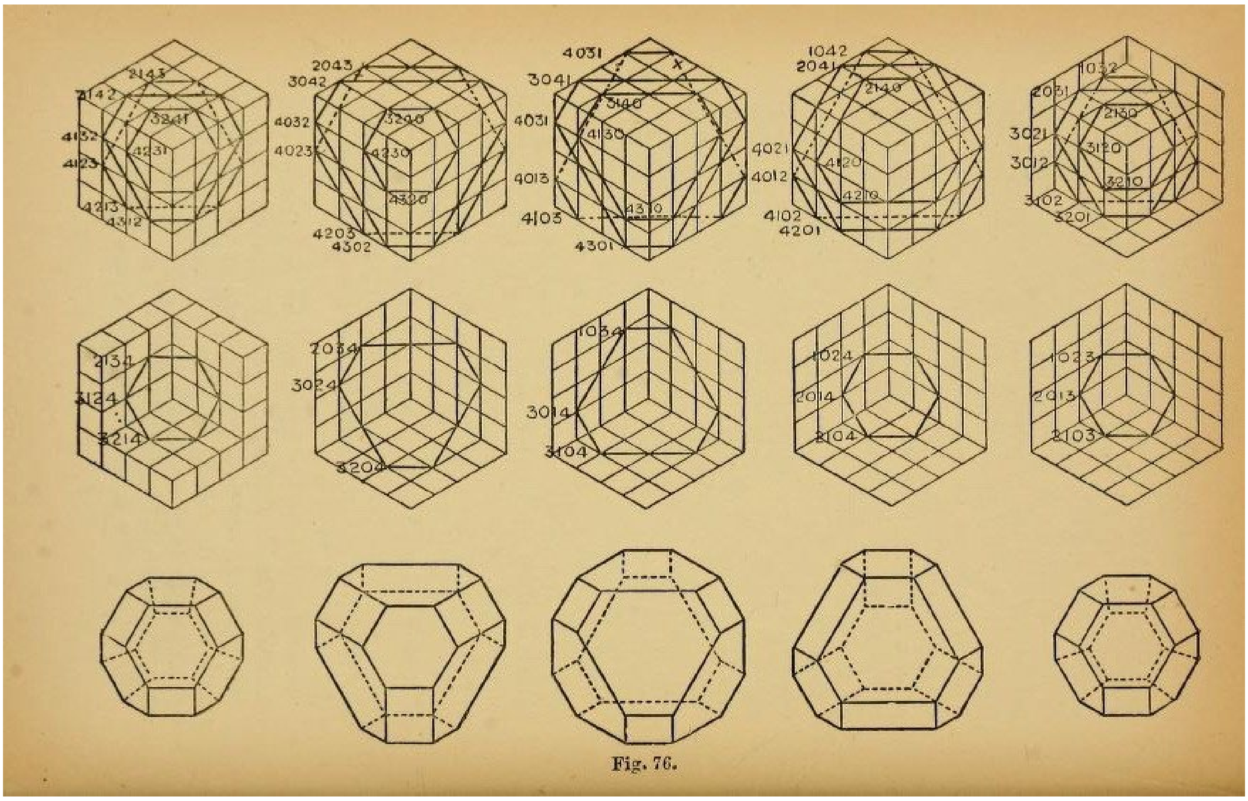


Fig. 76.

Charles Howard Hinton – The Fourth Dimension

It seems apt to end with an open question. How many people have set out on a walk in order to listen to the sun?

Throughout my research into the anatomical natures of the human inner ear, I spent a lot of time with the 19th century physicist, Ernst Mach. It soon became apparent that said research would not find a home here, however, it seems to have returned of its own accord.

Among many other things, Mach studied the semicircular canals, conducting ingenious experiments in order to deduce the roles of the otolith organs in the perception of horizontal and vertical motion. He also, after reading *The Waste Books* of polymath George Christoph Lichtenberg, in which the phrase, 'I think', was switched out for 'It thinks', began to deny the centrality of the ego, claiming that the self is a series of interrelated conscious representations and sensations, a continual flux.

However, what has caused me to pay such attention to Mach at this time, in a corner of these notes, is his recounting of an childhood memory in which he heard 'the hissing of the sun'.

The electromagnetic nature of a star such as the sun is quite well known, what seems less well known is the sensitivity of the semicircular canals to electromagnetic fields

We can't listen to the sun with our auditory labyrinths, at least it feels that way, but might it be possible to listen with our semicircular canals, wherein listening is a kind of balance?

This has led me to imagine a fourth semicircular canal, a hyper-canal, one that is primed to receive vibration in a higher dimension.

From what I'm given to understand, the semicircular canals are the most 'suitable' organ to receive electromagnetism, a theory partially based on the fact that endolymph is sensitive to electromagnetic fields.

We might equivocate this fourth canal as a hologrammatic projection, encircling our bodies, engaged in the imagined experience of a celestial soundwalk, listening to the electromagnetic fields of the solar system.