Within a sensory system, the stimuli is coupled to its corresponding receptors

A sensory system will detect properties of the stimuli:

- Modality - type of stimuli (Vision hearing touch taste smell, proprioception, balance)
- Intensity - strength of the stimuli (loudness, light intensity)
- Duration
- Position - stereoptic, biaural

Sensory receptor function: transduce external stimulus to active potential in the nervous system.

Receptor potential characteristics: Stimulus causes a change in membrane conductance, lead to a electrotonic condcution restricted to the membrane surface, graded potential.

Frequency coding:

- Strength of the stimulus tranduced to the amplitude of the receptor potential, transduced to the frequency of firing of active potential in neurons.
- Can also code for the velocity of the stimulus:
    - higher velocity - higher firing frequency: phasic response.
    - Suatained stimuli leading to a sustained elevated firing frequency - tonic response.
    - Most fibres are phaso-tonic

The ear

- Outer ear
    - External structure is the auricle of pinna (cartilagenous structure), prominant structure include lobule, helix.
    - Auricle allows amplification of the sound by ~15dB, through the auditory canal, until reaching the tympanic membrane.
- Middle ear
    - Contains three bones in the air filled chamber (malleus, incus & stapes)
        - Hammer shaped malleus, intermediate incus, stapes surround an artery, connect to oval window.
    - Tensor tympani muscle connection allow acoustic reflex, muffling of ossicles, prevent loud noises to damage inner ear. Stapedius to the stapes. Co-contraction in animals, stapedius only in humans.
    - connect to the nasal-pharyngeal cavity via the eustachian tube (allow equalisation of pressure)
    - Allows impedance matching: area ratio between tympanic-oval window + ossicle lever action —> amplification of 20~30 dBs.
    - Otosclerosis or fluid filled middle ear can lead to conductive deafness
- Inner ear
    - The cochlea: fluid filled compartment
        - 1cm wide, 35mm coiled in 2.5 turns
    - 3 cochlea compartments: Oval window - Scala tympani | Basilar membrane | Sacla Media | Vestibular membrane | Scala vestibuli - Round window (pressure relief)
    - Tonotopic map: thick and narrow basilar membrane at the base, thin and wide membrane towards the apex, as sound travel through the scala tympani, different frequencies are detected at different position along the basilar membrane
    - Organ of corti, within the lumen of the scala media, on the other side of the basilar membrane. 4 rows of hair cells
        - Covered by tectorial membrane
        - 1 row of inner hair cells (IHC), innervated 95% affarent fibres , 3 row of outer hair cell connect 5% fibre

        - Outer hair cell bundles connected to the tectorial membrane, Inner hair cell are fluid coupled
    - Sound transduction: Sound wave travel in the scala tympani via the oval window, causes movement of the basilar membrane, tectorial membrane deflect the hair bundles towards the tallest cilia, opening of cationic channel, depolarisation, release glutamate to ANF
    - Auditory nerve fibres
        - Type I ANF innervate IHC (20 ANF - 1IHC) , Type II ANF innervate OHC (1 ANF - 100OHC)
        - Synapse in the spiral ganglion cells, then project to the auditory cortex, form tonotopic map (lowest frequency to highest frequency)
    - Frequency coding:
        - Phase locking: ANF AP firing correspond to peak on the sin wave of sound wave, allow interpretation of sound, up to 3000 Hz
        - Place mapping: each position on the basilar membrane is tuned to a particular frequency, the tuning of the nerve can be detected by exposing the corresponding area of basilar membrane to all frequencies with high to low amplitude. The nerve is most sharply tuned to a particular frequency with lowest threshold amplitude.
    - Intensity coding:
        - Individual IHC coding: different types of ANF with different threshold connect to the IHC, provide dynamic range of intensity sensitivity. Lower threshold - higher spontaneous firing rate, more sensitive to low amplitude sound
        - Population intensity coding: As amplitude of the sound increase, broader range of IHC along the frequency axis of cochlea will be stimulated.
    - Injury to the inner ear, nerve deafness, can not hear even with tuning fork contacting temporal bone

- Vestibular labryinth: 3 semi-circular canals + 2 otolith organs
    - 3 semi-circular canals detect rotational acceleration (three orthogonal planes)
        - Crista ampullaris: set within the bone in an endolymph filled space. Crista contain sensory ciliated epithelium cells.
        - Cupula is a gelatinous structure on top of sensory hair cells.
        - Hair cell: around 100 actin rich stereocilia on the hair cells, tip link with cadherin23/15 in staircase manner, kinocilia is the tallest true cilia. Fluid movement causes stretching of cadherin protein, opening cationic channel, induce receptor potential. Opposite direction close channel, hyperpol.
        - During movement, fluid in the compartment stimulate hair cells due to inertia receptor potential transmitted across the synapse to the sensory nerves, and relayed to the vestibular nerve.
        - Spontaneous firing at rest, increase in AP firing rate with favourable rotation direction, decrease with null direction, opposite tuning between L/R ear.
        - Adaptation: tip link cadherin can reset with sustained stimulation, result in adaptation.
            - decrease in RP amplitude, AP frequency, slow and quick adaptation allows phasic and tonic responses.
            - Adaptation often result from desensitisation or synapse modulation from other sources
    - 2 otolith organs detect linear (Utricle) and vertical (saccule) acceleration

Hearing

Pitch: meadured by Hertz: cycles per second, represent the frequency of the sound. 1/period (length of a cycle)

Amplitude represent the loudness of the sound.

Human hearing range: 20Hz to 20000Hz, most sensitive at 1000Hz to 4000Hz, talking range with lowest hearing threshold

Sound pressure level is measured by decibels:

μPa or dB = 20 log (Pt/Pr), Pt is test pressure, Pr is threshold pressure (just audible)

An increase of 20 μPa is 10 times louder