



The Brain, Biology and Cognition (BBC)

Mechanisms of perception:
Hearing, touch, and attention.

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Principles of Sensory System Organization



- **Sensory areas of cortex are of 3 different types:**
- **Primary cortex** – Main input from thalamic relay nuclei
 - E.g., striate cortex receives input from the lateral geniculate nucleus
- **Secondary** – input mainly from primary and other secondary cortex areas within the sensory system
- **Association** – input from more than one sensory system, usually from secondary sensory cortex

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Principles of Sensory System Organization



- **Interactions characterised by 3 main principles:**

1. **Hierarchical Organization.....**
 - **Specificity** and **complexity** increases with each level.
- Each level receives most input from lower layers and adds another level of analysis before passing on up the hierarchy.
- General process of perceiving is split into 2 phases
 - **Sensation** – detecting a stimulus
 - **Perception** – integrating/understanding the stimulus

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Principles of Sensory System Organization

2. Functional Segregation exists in the system – distinct functional areas exist within a level and specialize in different kinds of analyses.

3. Parallel Processing exists – simultaneous analysis of signals along different pathways of a network.

- 2 parallel streams exist:
 - One influences behaviour through conscious awareness
 - Other influences behaviour without conscious awareness

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Principles of Sensory System Organization

Former Model

Current Model

Characterised by division of labour: specialised areas at multiple levels are interconnected by multiple parallel pathways. E.g., each area of the visual system is specialised for perceiving aspects of a visual scene (shape, colour, movement, etc.)

Perception is product of combined activity of different interconnected cortical areas.

Also top-down processing: neurons carry signals down the hierarchy.

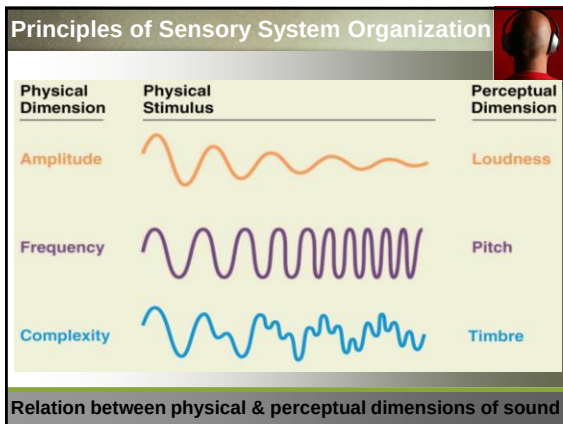
2 models of sensory system organization: former model was hierarchical, functionally homogeneous, and serial; current model, more consistent with evidence, is hierarchical, functionally segregated, and parallel.

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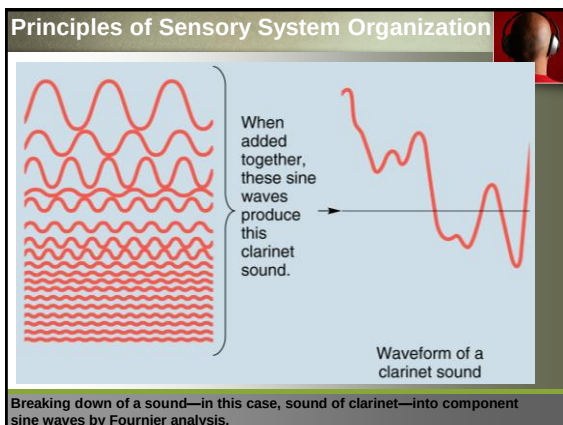
Auditory System

- **Function is to perceive sound**
- **Natural sounds are complex patterns of vibrations of air molecules that stimulate the auditory system**
- **We hear molecule vibrations between 20-20,000 hz**
- **Fourier analysis (mathematical procedure) breaks natural sounds down into sine waves**
- **Our system understands sound through relationship between natural sound and perceived frequency**

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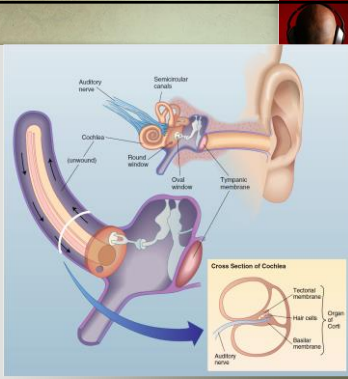
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Complete Questions 1 and 2 on the Mechanisms of Hearing Worksheet

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The Ear

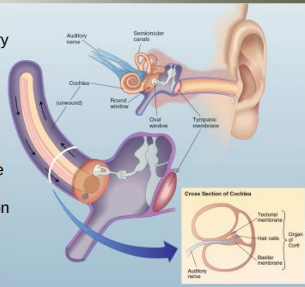
- Sound waves enter auditory canal and cause tympanic membrane (eardrum) to vibrate
- Sets in motion bones of middle ear, ossicles, which trigger vibrations of oval window
- Ossicles = hammer (malleus), anvil (incus), stirrup (stapes)
- Vibration of oval window sets in motion fluid of cochlea
- Cochlea's internal membrane, organ of Corti, is the auditory receptor organ



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The Ear

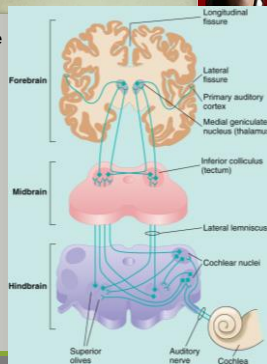
- Pressure change at oval window travels along organ of Corti as wave
- Corti is composed of:
 1. Basilar membrane – auditory receptors (hair cells)
 2. Tectorial membrane – rests on hair cells
- Stimulation of hair cells triggers action potentials in auditory nerve
- Tonotopic (frequency) organization of basilar membrane and most auditory system components



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From the Ear to the Primary Auditory Cortex

- Axons of each auditory nerve synapse in ipsilateral cochlear nuclei
- Projections lead to superior olives on both sides of brain stem
- Axons project via lateral lemniscus to the inferior colliculi
- Axons project from inferior colliculi to medial geniculate nuclei of thalamus
- Thalamic neurons project to primary auditory cortex



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Subcortical Mechanisms of Sound Location

Lateral and medial superior olives react to differences in what is heard by the two ears

- Medial – arrival time differences
- Lateral – amplitude differences

Both project to superior colliculus

- Deep layers of superior colliculus are laid out according to auditory space, allowing location of sound sources in world;
- Shallow layers are laid out retinotopically

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Auditory Cortex

- Located in temporal lobe within lateral fissure.
- **Core** region: includes primary cortex
- **Belt** surrounds core region (secondary cortex)
- Secondary cortex outside belt = **parabelt** areas
- Organized in functional columns with neurons responding optimally to sounds in same frequency range.

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What Sounds Should Be Used to Study Auditory Cortex?

- **Reasons research on auditory system has fallen behind:**
- **Lack of understanding of dimensions along which auditory cortex evaluates sound**
- **Cells that respond to complex sounds are not understood**
- **Difficult to know how to probe system with right acoustic stimuli.**

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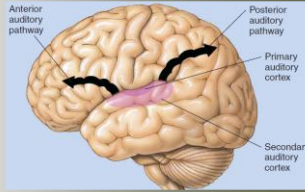
Two Streams of Auditory Cortex

- Auditory signals conducted to 2 areas of association cortex:

- Prefrontal cortex
- Posterior parietal cortex

- Anterior auditory pathway involved in identifying sounds (what)

- Posterior auditory pathway involved in locating sounds (where)



Hypothesised anterior and posterior pathways

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Auditory-Visual Interactions

Some posterior parietal neurons have visual and auditory receptive fields

- Interaction in primary sensory cortices indicate sensory system interaction is early and integral part of sensory processing
- Not just something that happens after system has completed analysis.

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Where Does the Perception of Pitch Occur?

- Most auditory neurons respond to changes in frequency rather than pitch
- But 1 area anterior to primary auditory cortex has neurons that respond to pitch not frequency
 - May be where frequencies of sound are converted to perception of pitch?

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Effects of Damage to the Auditory System



- Lesions in rats = few permanent hearing deficits.
 - Suggests subcortical circuits more complex than once thought.
- Lesions in monkeys and humans hinder sound localization and pitch discrimination

Deafness in humans

- Total deafness is rare, due to diffuse multiple pathways existing and continue to carry flow of information.
- Two kinds: conductive deafness (damage to ossicles) and nerve deafness (damage to cochlea)
 - Partial cochlear damage results in loss of hearing at particular frequencies

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Somatosensory System: Touch and Pain



Somatosensory system = 3 separate interacting systems:

- Exteroceptive – senses external stimuli
- Proprioceptive – monitors info on body position
- Interoceptive – provides info on body conditions (e.g., temperature and blood pressure)



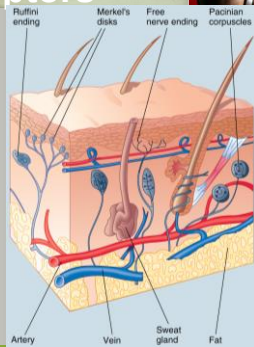
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Cutaneous Receptors



Cutaneous = relating to or affecting the skin...

1. **Free nerve endings:** Sensitive to temperature and pain
2. **Pacinian corpuscles:** Adapt rapidly, large/deep; onion-like & respond to displacement of skin
3. **Merkel's disks:** adapt slowly to gradual skin indentation
4. **Ruffini endings:** adapt slowly to gradual skin stretch



Four cutaneous receptors that occur in human skin

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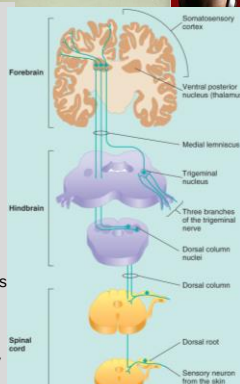
Complete Questions 3 and 4 on the Mechanisms of Hearing Worksheet

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Two Major Somatosensory Pathways

1. Dorsal-column medial-lemniscus system

- Touch & proprioception
- Sensory neurons enter spinal cord via dorsal root & ascend ipsilaterally in dorsal columns and synapse in dorsal column nuclei of the medulla.
- Axons of dorsal column nuclei neurons cross over & ascend into medial lemniscus to contralateral ventral posterior nucleus of the thalamus.
- Ventral posterior nuclei receive input via 3 branches of trigeminal nerve carrying somatosensory info from contralateral areas of face.
- Most neurons of ventral posterior nucleus project to primary somatosensory cortex, others project to secondary somatosensory cortex.

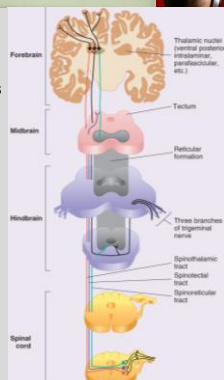


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Two Major Somatosensory Pathways

2. Anterolateral system

- Most dorsal root neurons synapse as soon as they enter the spinal cord.
- Axons of most second order neurons cross to other side but ascend to brain in contralateral anterolateral portion of spinal cord, but some also ascend ipsilaterally.
- Anterolateral system comprises 3 tracts:
 1. Spinothalamic (projects to ventral posterior nucleus of thalamus);
 2. Spinoreticular (projects to reticular formation)
 3. Spinotectal (projects to the tectum).
- If both paths damaged by spinal injury person will not be able to feel any body sensations below level of cut.



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Cortical Areas of Somatosensation



- Primary somatosensory cortex (SI):
 - Includes Postcentral gyrus
 - Has Somatotopic organisation (somatosensory homunculus) – more sensitive, more cortex
 - Input largely contralateral
- Secondary somatosensory cortex mainly receives input from primary somatosensory cortex
- Somatotopic; input from both sides of the body
- Much output from SI and SII goes to association cortex in posterior parietal lobe

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Somatosensory System & Association Cortex



- **Somatosensory signals conducted to highest level of sensory hierarchy:**
 - to areas of association cortex in prefrontal and posterior parietal cortex.
- **Posterior parietal cortex contains bimodal neurons**
 - Neurons that respond to activation of two different sensory systems
 - Somatosensory and visual stimuli.

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Somatosensory Agnosias



1. **Astereognosia** – inability to recognize objects by touch
 - pure cases are rare – other sensory deficits are usually present
2. **Asomatognosia** – failure to recognize parts of one's own body
 - Usually associated with damage to right posterior parietal lobe which affects left side of body.

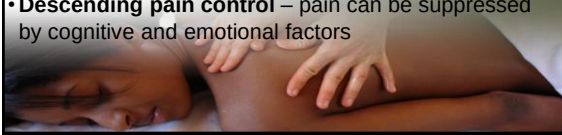


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Perception of Pain

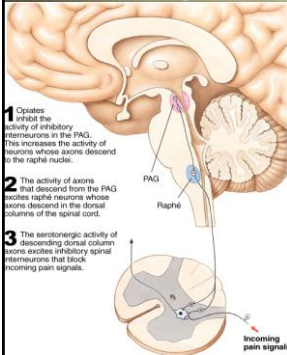


- Despite unpleasantness, **pain is adaptive** & needed
- **No obvious cortical representation of pain**
- Painful stimuli can elicit pain in primary & secondary somatosensory cortex but removal not associated with changes in threshold for pain.
- Anterior cingulate gyrus appears involved in emotional component of pain
- **Descending pain control** – pain can be suppressed by cognitive and emotional factors



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Descending Pain Control



Circuitry identified by studies:

- Electrical stimulation of the periaqueductal gray (PAG) has analgesic effects
- PAG have receptors for opiate analgesic drugs (e.g., morphine)
- Existence of endogenous opiates (natural analgesics) endorphins could be isolated

Basbaum and Fields's (1978) model of the descending analgesia circuit

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Neuropathic Pain



- Severe chronic pain in absence of recognizable pain stimulus
- Exact mechanism unknown but likely from pathology of nervous system linked to injury
- Some evidence for aberrant (diverging from normal function) glial cell signals triggering neural pain pathways

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Neural Mechanisms of Attention

- Consensus that prefrontal cortex and posterior parietal cortex play major role in directing top-down attention
- Selective attention thought to work by strengthening neural responses to attended-to aspects and weakening responses to others

Cocktail-party phenomenon:

Indicates processing of information not attended.



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Simultanagnosia

Simultanagnosia – difficulty attending to more than one visual object at a time.

Typical cause: bilateral damage to dorsal stream of posterior parietal cortex, which is responsible for visually localizing objects in space.



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