Sensory areas distinguish themselves from other parts of cortex by:
1) Densely packed, darkly Nissl stained small neurons in middle cortical layers (layer 4).
2) Densely myelinated.
3) High levels of CO.

Papers:
Han et al., Nature Neuroscience 2007
Andermann et al., Nature Neuroscience 2006
Center/Surround Receptive Field: Difference of Gaussians Model

Center Component

Receptive Field Profile

Surround Component
Emergence of Orientation Selectivity

ON-Center Ganglion Cell

OFF-Center Ganglion Cell

Light Spot In Center

Dark Spot in Center

Light Spot in Surround

Diffuse Light Covering Center and Surround

Stimulus On
(A) Experimental setup

Light bar stimulus projected on screen

Recording from visual cortex

(B) Stimulus orientation

Stimulus presented

Time (s)

0 1 2 3
Cortical orientation response emerges from feed forward LGN input

Reid and Alonso, 1995
Mapping RF with Flashing Spots

Lample, Anderson, Gillespie and Ferster, 2001
Orientation selective ‘simple’ cell

‘Complex’ cell
Maps in the visual system

Maps in normal and binocularly deprived cats

Contra eye

Ipsi eye

P14 Normal

P19 BD
Critical period for plasticity

Critical Period for Monocular Deprivation (Olson and Freeman, 1980)

<table>
<thead>
<tr>
<th>Age (weeks)</th>
<th>Normal</th>
<th>Binoc Dep</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>1</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>2</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>3</td>
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<tr>
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<tr>
<td>5</td>
<td>0.7</td>
<td>1.0</td>
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<tr>
<td>&gt;6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Critical Period for Binocular Deprivation
Maps in normal and deprived ferrets

P39 ferret

White et al., 2001
Maps in normal and deprived ferrets

White et al., 2001
Higher order centers for vision

Where?
Dorsal Stream

What?
Ventral Stream
Mapping the Somatosensory and Motor Cortex

Foerster and Penfield, 1930

Penfield and Boldrey, 1937
Somatosensory sensation

Anterolateral

Intralaminar and medio-dorsal nuclei

Dorsal root ganglion

Primary somatosensory cortex

Pain, temperature, crude touch

Primary sensory neuron

Dorsal root entry zone

Secondary sensory neuron

Lissauer’s tract

Spinothalamic tract

Spinothalamic tract

Spinomesencephalic tract

Spinoreticular tract

Anterior commissure

Ventral posterior lateral nucleus of the thalamus

TABLE 12.6 Analogous Trigeminal and Spinal Somatosensory Systems

| NUCLEUS                          | SENSORY MODALITIES           | MAIN PATHWAY TO THALAMUS | MAIN THALAMIC NUCLEUS*
|----------------------------------|------------------------------|--------------------------|--------------------------
| Trigeminal sensory systems       |                              |                          |                          |
| Mesencephalic trigeminal nucleus | Proprioception               | Trigeminal lemniscus     | VPM                      |
| Chief trigeminal sensory nucleus | Fine touch, dental pressure  | Trigeminal lemniscus     | VPM                      |
| Spinal trigeminal nucleus        | Crude touch, pain, temperature | Trigeminal lemniscus     | VPM                      |
| Spinal sensory systems           |                              |                          |                          |
| Posterior column nuclei          | Fine touch, proprioception   | Medial lemniscus         | VPL                      |
| Dorsal horn                      | Crude touch, pain, temperature | Spinothalamic tract      | VPL                      |

*VPL, ventral posterior lateral nucleus; VPM, ventral posterior medial nucleus.
Somatosensory ‘Barrel’ Map in Rodents
Rodent whisker-barrel system
Barrels have a presynaptic and postsynaptic component.
Barrel Cortex Plasticity

Whiskers → Trigeminal ganglion → Brainstem → Thalamus → 'Barrel' Cortex

Normal PND 0 lesion PND 4 lesion
Intact whiskers are necessary for barrel formation
Supernumary whiskers cause supernumary barrels

Van der Loos et al., 1986
Thalamocortical synapse development

Diagram showing the development of thalamocortical synapses.

- **Late** stage: Glutamate release, NMDA receptor (2B) activation, and calcium influx.
- **Early** stage: Glutamate release, AMPA receptor activation, sodium influx, and calcium influx.
Disturbed Barrels in CxNR1 KO

wt   CxNR1 (-/-)

CO

tenascin

Nissl

Iwasato et al., 2000
Somatosensory Cortex

- frontal pole
- central sulcus
- temporal lobe
- postcentral gyrus
- occipital lobe
Parallel processing pathways in somatosensory cortex.

Area 3a: Proprioception (e.g. from muscle spindles)

Areas 3b: ‘Primary’ somatosensory cortex cutaneous receptors

Area 2: Mixed proprioception and cutaneous touch, mostly about size and shape

Area 3b is ‘primary’ (S1) somatosensory cortex
Area 1 is a ‘secondary’ somatosensory cortex receiving most drive from area 3b (mirror reversed somatotopy from area 3b)
Areas 3a and 2 each have a complete map
S1 modules may be further subdivided (functionally) into regions with slowly adapting (SA) and rapidly adapting (RA – ‘flutter’) responses.
Figure 2

Catania, 1995
Auditory Circuits

- Medial geniculate nucleus (MGN)
- Brachium of inferior colliculus
- Inferior colliculus
- Lateral lemniscus
- Superior olivary nuclear complex
- Inferior cerebellar peduncles
- Trapezoid body
- Dorsal cochlear nucleus
- Spiral ganglion cells
- Ventral cochlear nucleus

Central Auditory Pathway
- auditory cortex
- medial geniculate nucleus
- inferior colliculus
- lateral lemniscus
- cochlea
- auditory nerve
- ventral cochlear nucleus
- superior olivary complex
A
Primary auditory cortex
Secondary auditory cortex

B
Corresponds to apex of cochlea
Corresponds to base of cochlea

500 Hz
1000 Hz
2000 Hz
4000 Hz
8000 Hz
16,000 Hz
Auditory Cortex in Primate

Three ‘Primary’ (core) auditory cortices: A1; R; RT

Core (A1’s) and Belt (A2’s)

Where? (localization)

What? (identification)
Auditory Cortex Circuitry in Primate

Hierarchical

Frontal lobe
Temporal lobe
Parabelt
Bolt
Core
Thalamus
Midbrain
Lateral lemniscus
Superior olivary complex
Contra cochlear nucleus

Dorsal - Where?
Ventral - What?
Polymodal
Human language areas

- Broca's area
- Primary motor cortex
- Wernicke's area
- Arcuate fasciculus
- Angular gyrus
- Primary auditory cortex
- Primary visual cortex
Auditory Cortex in Rodent

Core:
- A1 = Primary field
- AFF = Anterior auditory field

Belt:
- DP = Dorsoposterior
- VP = Ventroposterior
- D = Dorsal field
- AV = Anterior ventral
- V = Ventral field
- VM = Ventromedial field

Gerbil diagram with areas labeled.
Tonotopic Map Plasticity

(a) Auditory Cortex

(b) Frequency in kHz

[Image: Current Opinion in Neurobiology]
Broadly tuned at trained frequency actually makes for poor frequency discrimination.

Han et al., 2007
Cross-modal plasticity

A. Wildtype Mouse

B. Congenitally Deaf Mouse

C. Normal Opossum

D. Bilateral Enucleate Opossum

Legend:
- Vis: Visual
- Som: Somatosensory
- Aud: Auditory
- Som, Vis, Som + Vis
- Som, Aud, Som + Aud
Retinal projections routed to Auditory Cortex: Cross-modal plasticity

Roe et al., 1990
End
Auditory/visual map of space
Prism rearing shifts auditory map

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Sensitive period for map plasticity

Copyright © 2002, Elsevier Science (USA). All rights reserved.
Map plasticity mediated by changes in pattern of connections

A  Before Prisms

B  After Prism-rearing

Copyright © 2002, Elsevier Science (USA). All rights reserved.
Incremental training increases adult plasticity

Owls at least 2 years old

Linkenhoker and Knudsen, 2002
Plasticity in Adult Somatosensory Cortex

(A) Owl monkey brain

(B) Normal hand representation

(C) Hand representation 2 months after digit 3 amputation
Plasticity in Adult Somatosensory Cortex
‘Whisker pairing’ induces receptive field plasticity in adult barrel cortex

- Control
- D1&D2 paired
- D2&D3 paired

Barrel (Layer IV) Cells

- D-AP5
- L-AP5

D1&D2 paired; recording in D2 barrel
Adult Auditory Cortex Plasticity

Recanzone, Schreiner and Merzenich, 1993
End