Vision

I. Introduction
II. The Nature of Light
III. Anatomy of the Visual System
IV. Analysis of Visual Information in the Retina
V. Analysis of Visual Information in the Cortex
I. Introduction

- Sensation: the process of converting physical energies into the language of the brain.
- Accomplished by **sensory receptors** (specialized neurons) that perform **transduction** (or translation)
- These receptors show **receptor potentials** (gradual voltage shifts) instead of action potentials
II. The Nature of Light
III. Anatomy of the Visual System
Section of the Human Eye

- Eye muscle
- Ligament
- Iris
- Pupil
- Lens
- Cornea
- Ciliary muscle
- Sclera (the white of the eye)
- Retina
- Fovea
- Blind spot
- Optic nerve

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Blind Spot
Cellular Structure of the Mammalian Retina

- Retinal ganglion cells
- Amacrine cells
- Bipolar cells
- Horizontal cells
- Cone receptors
- Rod receptors

Light

To blind spot and optic nerve

Back of eyeball

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cones; but, at either side of the fovea, the density of rods is higher, which is why our vision is not so sharp at the edges. A final difference between rods and cones is their sensitivity to light. Although rods and cones both have pigments, rods have one pigment, whereas cones have three different types of these three cone pigments. Therefore, for color vision (one type in the rods and three types
Blue= rods  Green = Cones
Distribution of Cones and Rods over the Human Retina

Source: Adapted from Lidsay & Norman, 1977.

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Response of Rods to Light

In the DARK

1. Rhodopsin molecules are inactive.
2. Sodium channels are kept open by cGMP.
3. Sodium ions flow into the rods partially depolarizing them.
4. Rods continuously release glutamate.

In the LIGHT

1. Light bleaches rhodopsin molecules.
2. As a result, cGMP is broken down and sodium channels close.
3. Sodium ions cannot enter rods, and as a result, the rods become hyperpolarized.
4. Glutamate release is blocked.
Pathways from the Retina

• In the brain, retinal ganglion axons travel to...
  – the lateral geniculate nucleus (LGN) and then the primary visual cortex (V1, area 17): more to come...
  – the hypothalamus: control bodily/circadian rhythms
  – the tectum (superior colliculi), pulvinar (thalamus), and then visual association cortex: orienting eyes to things we see and hear
Retinal ganglion cell axons synapse with three types of neurons in the LGN

• Magnocellular layer (M layer) has larger cell bodies
  – Layers 1 & 2
  – Process information related to form, movement, depth, small changes in brightness
  – Connected mostly with rods
• Parvocellular layer (P layer) has smaller cell bodies
  – Layers 3 through 6
  – Process information related to color and fine detail
  – Connected mostly with cones
• Koniocellular layer
  – Connected mostly with blue cones
The Retinotopic Map

• There is a distorted map of our retina (which registers the visual world) at several different places in the brain

• Each place in our visual field is represented by the activity of particular neurons in several different parts of our visual system

• This map of the retina is represented and maintained in the LGN, primary visual cortex (V1), and other visual processing areas
  – Distinction of M and P layers started in the LGN is maintained in V1 as well
IV. Analysis of Visual Information in the Retina
Convergence of Cones and Rods

Low Convergence in Cone-Fed Circuits
- Retinal ganglion cell
- Bipolar cell
- Cone

High Convergence in Rod-Fed Circuits
- Retinal ganglion cell
- Bipolar cell
- Rod

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Receptive Field Example
Mach Bands

What is there

What you see

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The three types of cones are called “blue,” “green,” and “red.” These names loosely refer to the frequencies of light to which each cone is maximally sensitive (the peak sensitivities are 419, 531, and 559 nm respectively).
Yellow on, blue off
Blue on, yellow off
Red on, green off
Green on red off
V. Analysis of Visual Information in the Cortex
Aspects of Vision Processed in the Primary Visual Cortex (V1)

• Orientation and Movement
• Spatial Frequency and Texture
• Retinal disparity/binocular disparity disparity
• Color
• NOTE: all functions appear to be processed by distinct sets of V1 neurons
Feature Detector
Modular Organization of V1

• V1 appears to be organized into modules
• Each module receives input from both eyes about one small part of the visual field
• Input from each eye is separated into “ocular dominance columns” within the module
• CO Blobs: color and low spatial frequency
• Outside of CO Blobs: orientation, movement, spatial frequency, texture, binocular disparity
Hubel and Wiesel’s Model

A block of tissue such as this is assumed to analyze visual signals from one area of the visual field.

Half the block of tissue is presumed to be dominated by right-eye input and half by left-eye input.

Each slice of the block of tissue is presumed to specialize in the analysis of straight lines in a particular orientation.
Hubel and Livingstone's Model

Blobs

Lower layer IV

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V. Analysis of Visual Information in the Cortex
Visual Association Cortex (areas outside of V1)

• Dorsal Stream
  – Projects from just outside V1 to the parietal lobe
  – Helps us to figure out where things are
  – Often called the “where” or “how” pathway

• Ventral Stream
  – Projects from outside of V1 to the temporal lobe
  – Involved in identifying what we see
  – Often called the “what” pathway
Figure 8-16

Information travels from the lateral geniculate nucleus to layer IV of cortical visual area 1. Layers 1 through 4 project to layer IVβ; layers 5 and 6 project to layer IVα. Information from the two eyes is segregated by layers in the LGN, and the LGN maintains this segregation in its projections to the cortex.

Information from each eye travels to adjacent columns in cortical layer V1. In a horizontal plane through V1 (top right), there is a zebrilike effect of alternating columns in the cortex. These columns are referred to as ocular dominance columns.

Sleep and Biological Rhythms

I. Introduction
II. Measuring Sleep
III. Stages of Wakefulness and Sleep
IV. Why Do We Sleep?
V. Physiological Mechanisms of Sleep
VI. Biological Clocks
I. Introduction
II. Measuring Sleep

• EEG
• EMG
• EOG
Awake

Alpha activity  Beta activity

Stage 1 sleep

Theta activity

Stage 2 sleep

Sleep spindle  K complex

Stage 3 sleep

Delta activity

Stage 4 sleep

Delta activity

REM sleep

Theta activity  Beta activity
Figure 1: Hypnogram for a normal adult[^2]
Dolphin Brain during Sleep

Right Hemisphere

Waking
Intermediate sleep
Slow-wave sleep
Waking

Left Hemisphere

Waking
Waking
Waking
Slow-wave sleep
## Neurotransmitters Involved in Arousal

<table>
<thead>
<tr>
<th>Neurotransmitter</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norepinephrine</td>
<td>Locus coeruleous (pons)</td>
</tr>
<tr>
<td>Acetylcholine</td>
<td>Basal forebrain and reticular formation (in pons and medulla)</td>
</tr>
<tr>
<td>Serotonin</td>
<td>Raphe nuclei (pons and medulla)</td>
</tr>
<tr>
<td>Histamine</td>
<td>Tuberomammillary nucleus (hypothalamus)</td>
</tr>
<tr>
<td>Orexin (Hypocretin)</td>
<td>Hypothalamus</td>
</tr>
</tbody>
</table>
Neural Control of Slow-Wave Sleep

- Ventrolateral preoptic area (basal forebrain, in front of the hypothalamus; vlPOA)
- Destruction -> insomnia, coma, & death
- Injection of adenosine into the basal forebrain produces sleep
- Sleep promoting brain area of the Sleep/Waking Flip-Flop (Sleep ON neurons)
Sleep/Waking Flip-Flop

Inhibited

Sleep-promoting region in vLPOA

Mutual inhibition

Activated

Brain stem and forebrain arousal systems

Flip-flop is “on”

ACh  NE  5-HT  Histamine

Alert Waking State

(a)
Sleep/Waking Flip-Flop

Activated
Sleep-promoting region in vIPoA

Mutual inhibition

Inhibited
Brain stem and forebrain arousal systems

ACh  NE  5-HT  Histamine

Flip-flop is “off”

Slow-Wave Sleep
Neural Control of REM Sleep

- REM ON region: sublaterodorsal nucleus (SLD) located in the dorsal pons
- REM OFF region: ventolateral periaqueductal gray matter (vlPAG) located in the midbrain
- These two structures make up the REM Sleep Flip-Flop
REM Sleep Flip-Flop

- Biological clock—time of day
- Hunger signals
- Satiety signals
- LH orexinergic neurons
- vIPAG
- SLD

Brain regions that control components of REM sleep
The Suprachiasmatic Nucleus (SCN)
The “Ticking” of the Circadian Clock

• Involves the cycling of proteins (such as Per, Cry & Tim) inside of SCN neurons
• The proteins rise and fall in a pattern that repeats about every 24 hours
• Demo
Reproductive Behavior

I. Sexual Development
II. Hormonal Influence of Sexual Behavior
III. Neural Influence of Sexual Behavior
I. Sexual Development
Gametes

- Almost all cells of the human body contain 23 pairs of chromosomes (46 Total) in their nuclei.
- Gametes (sperm and ova) have 23 individual chromosomes in their nuclei (23 Total).
Human Chromosomes
Sex Chromosomes
Organizational Effects

- Hormone effect that directly changes tissue differentiation and/or development
- Causes changes in structures of the organism
- Organizational effects occur early in development
- Not reversible
Activational Effects

• Effect of a hormone on the fully developed (or mature) organism
• Act on pre existing structures, causing some type of change
• Activational effects often depend on prior organizational effects
• Examples: changes to boys and girls with puberty, ovulation in women
| Primordial Gonads  
(bipotential or bisexual) |
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>Genetic Females (XX)</strong></td>
</tr>
<tr>
<td>←No SRY gene</td>
</tr>
<tr>
<td>Gonads become ovaries</td>
</tr>
<tr>
<td>No testicular hormones</td>
</tr>
<tr>
<td>Müllerian System Develops (feminization)</td>
</tr>
<tr>
<td>Wolffian System Withers (defeminization)</td>
</tr>
</tbody>
</table>
Sexual Differentiation Disorders/Intersexuality

- Androgen Insensitivity Syndrome (AIS)
- Persistent Müllerian Duct Syndrome
- Congenital Adrenal Hyperplasia (CAH)
- Turner’s Syndrome
Genetic male with AIS
II. Hormonal Influence on Sexual Behavior
Puberty

**Male**
- GnRH

**Female**
- GnRH

Gonadotrophic hormones

- Testis
  - Testosterone
- Ovary
  - Estradiol
Activational Effects of Sex Hormones at Puberty (See Figure 9.5 in Text)

<table>
<thead>
<tr>
<th>Hypothalamus</th>
<th>Anterior Pituitary</th>
<th>Gonads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secretes: GnRH (Gonadotropin Releasing Hormone)</td>
<td>Secretes: gonadotropic hormones (FSH &amp; LH)</td>
<td>Secrete: sex steroids</td>
</tr>
<tr>
<td>Hips widen, breast develop, and other changes</td>
<td></td>
<td>Facial hair, voice drops, and other changes</td>
</tr>
</tbody>
</table>

**Ovaries**
- Secrete: estradiol (some testosterone)

**Testes**
- Secrete: testosterone (some estradiol)
Sexual Orientation
Genetic Females

- Money et al. (1984) asked about sexual orientation of women with CAH
  - 37% homosexual/bisexual
  - 40% exclusively heterosexual
  - 23% refused to answer

- Kinsey Report (1943) data on sexual experience with another woman
  - 10% overall
  - 40% of women with prenatal androgen exposure
Genetic Females

• Goy et al. (1988) exposed developing female primates to androgens
  – As adults, these primates showed more male-typical behaviors
Genetic Males

• Androgen Insensitivity Syndrome
  – Behavior is often stereotypically feminine
  – Most are sexually attracted to men
  – They marry men and have average sex lives
Sexual Orientation & the Brain

• Sexual dimorphisms: brain area of behavior is different between the sexes

• Possible dimorphisms related to sexual orientation:
  – Two parts of the hypothalamus (the SCN and the INAH-3)
  – Anterior commissure
Heredity & Sexual Orientation

• Concordance rates for homosexuality among twins:

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<tr>
<th></th>
<th>Identical Twins (MZ)</th>
<th>Fraternal Twins (DZ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>52%</td>
<td>22%</td>
</tr>
<tr>
<td>Females</td>
<td>48%</td>
<td>16%</td>
</tr>
</tbody>
</table>
III. Neural Influence on Sexual Behavior
Male Rat

• Medial Preoptic Area (MPA)
  – Controls sexual behavior (mounting and pelvic thrusting)

• Medial Amygdala
  – Influences sexual motivation
Sexually Dimorphic Nucleus (SDN) of the Medial Preoptic Area (MPA)
Female Rat

- Ventromedial Hypothalamus (VMH)
- Controls sexual behavior (lordosis)