511-2018-10-16-perception-action
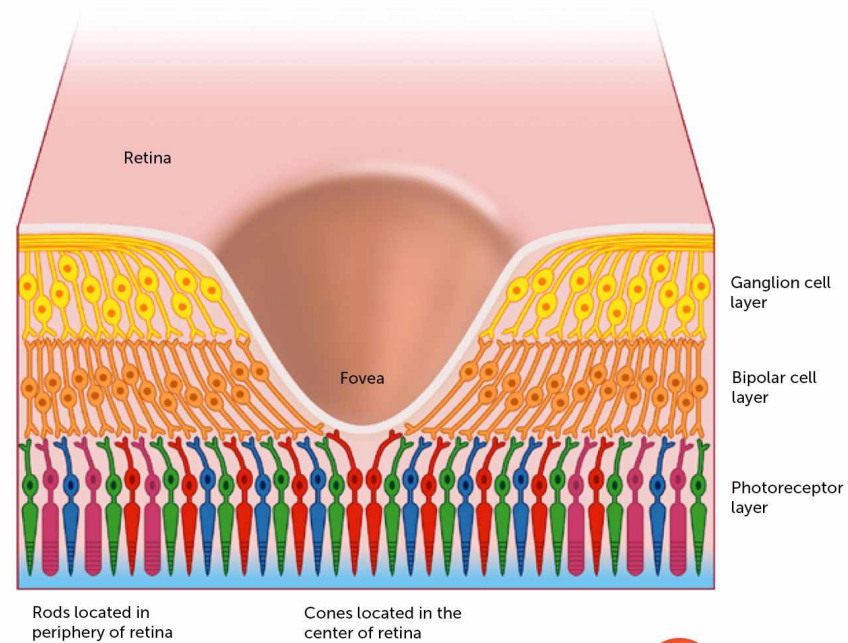
Rick Gilmore

2018-10-16 16:33:21

Today's Topics

- Wrap up on vision

- The neuroscience of action

- Quiz 2 available Friday

The *fovea*

Retina

Ganglion cell layer

Fovea

Bipolar cell layer

Photoreceptor layer

Rods located in periphery of retina

Cones located in the center of retina

brainHQ
from **Posit Science**

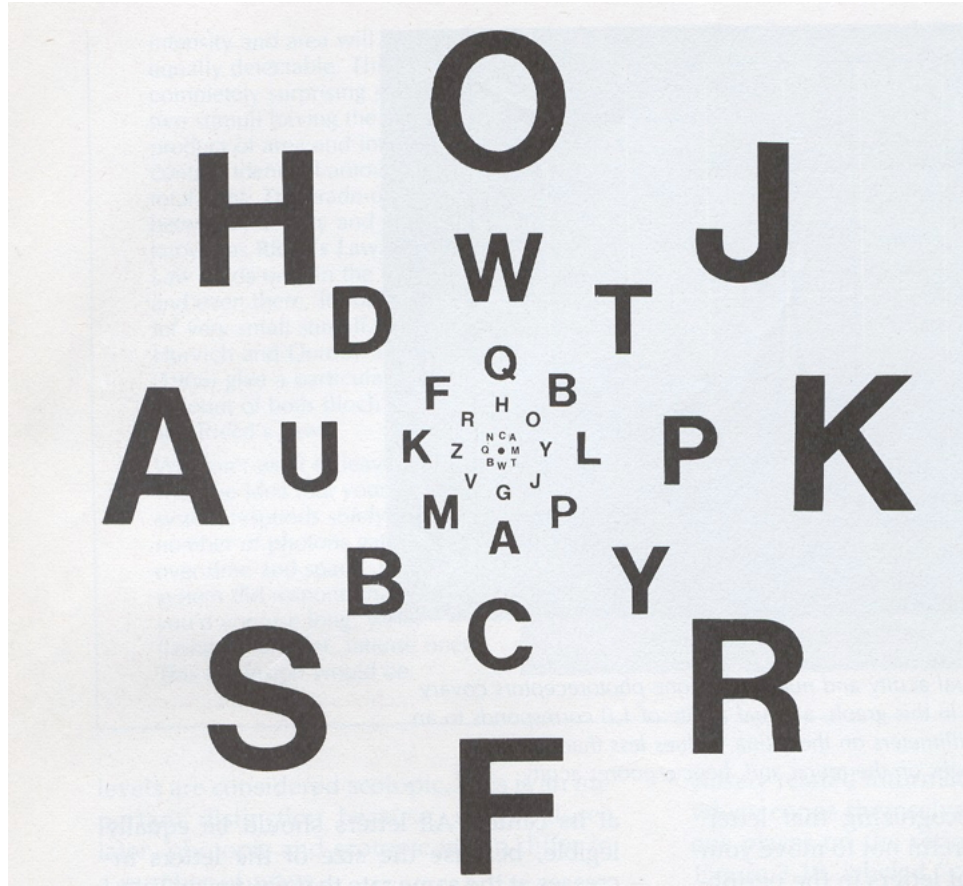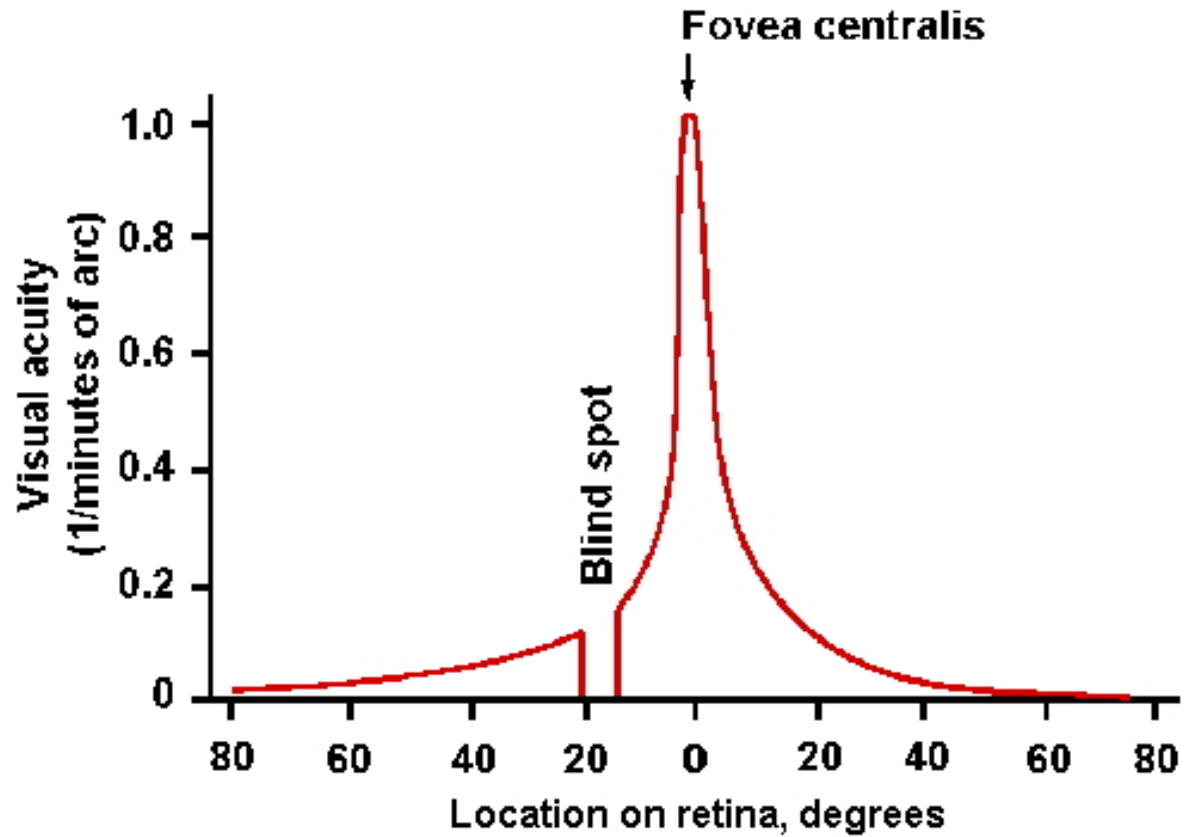http://www.brainhq.com/sites/default/files/fovea.jpg

The fovea

- Central 1-2 deg of visual field

- Aligned with visual axis

- *Retinal ganglion cells* pushed aside

- Highest *acuity* vision == best for details
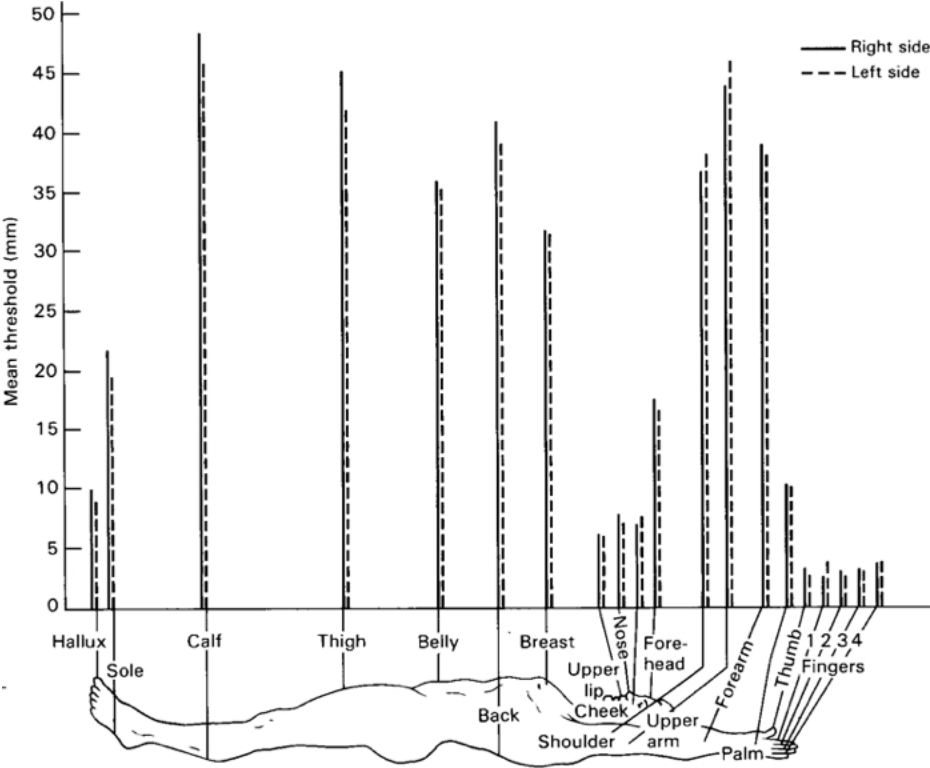
Acuity varies across fovea

Acuity varies across fovea

http://michaeldmann.net/pix_7/blndspot.gif

What part of the skin is like the fovea?
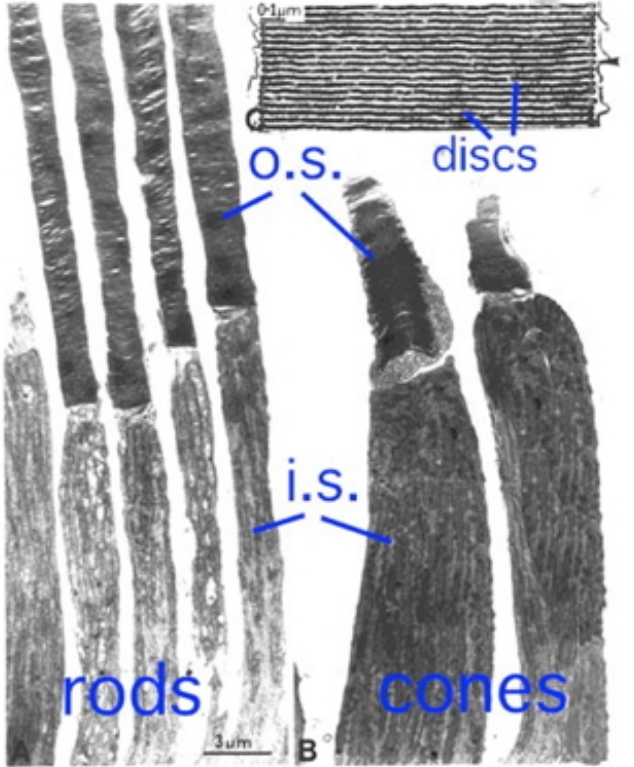
What part of the skin is like the fovea?

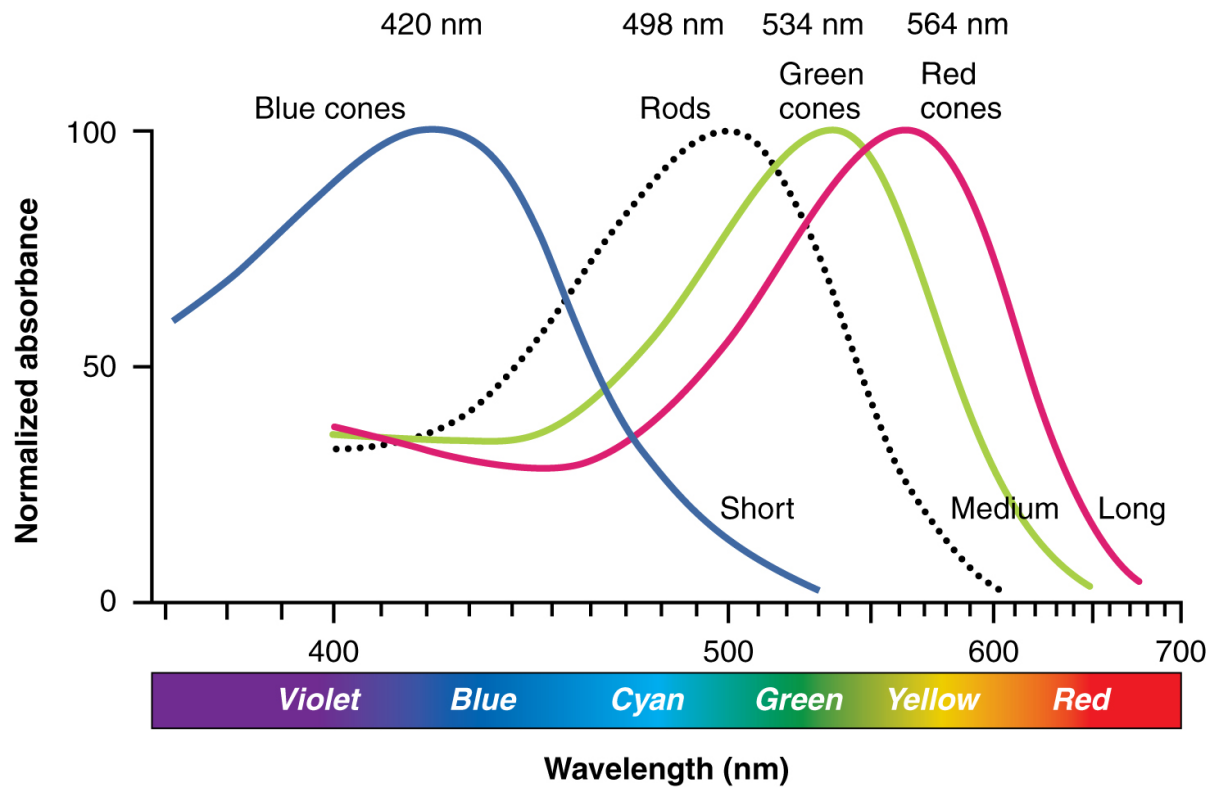# *Photoreceptors* detect light

Photoreceptors detect light

- *Rods*
    - ~120 M/eye
    - Mostly in periphery
    - Active in low light conditions
    - One wavelength range

Photoreceptors detect light

- *Cones*
  - ~5 M/eye
  - Mostly in center
  - 3 wavelength ranges

Photoreceptors "specialize" in particular wavelengths

Anatomy & Physiology, Connexions Web site. http://cnx.org/content/col11496/1.6/, Jun 19, 2013.

How photoreceptors work

- Outer segment
    - Membrane disks
    - *Photopigments*
        - Sense light, trigger chemical cascade
- Inner segment
    - Synaptic terminal
- Light *hyperpolarizes* photoreceptor!
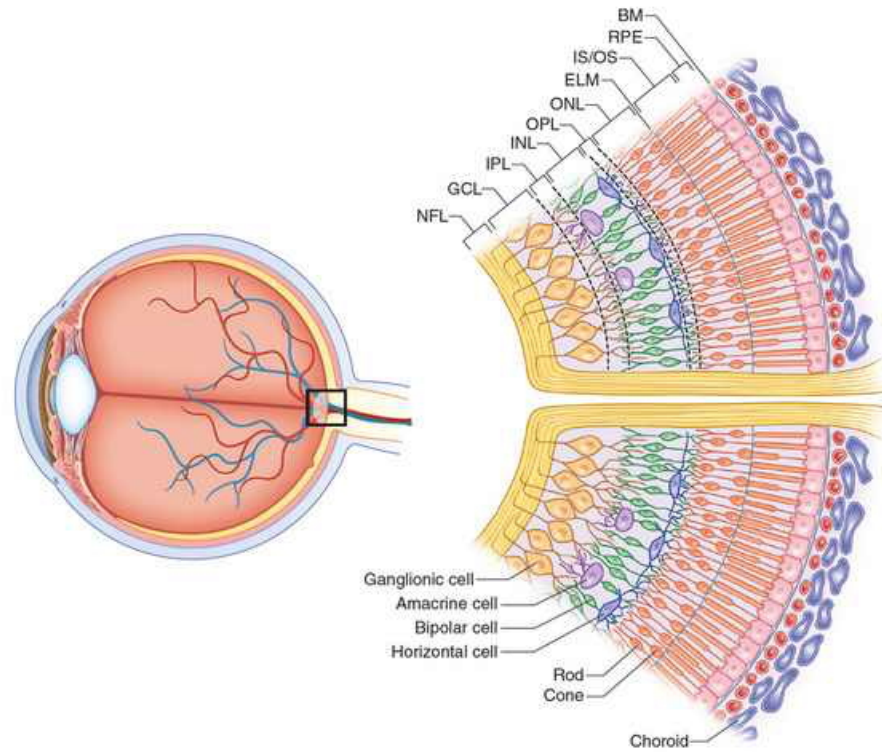   - The *dark current*

Retina

- Physiologically *backwards*
  - How?
- Anatomically *inside-out*
  - How?

Retina

- Physiologically *backwards*

    - Dark current

- Anatomically *inside-out*

    - Photoreceptors at back of eye

Retinal layers

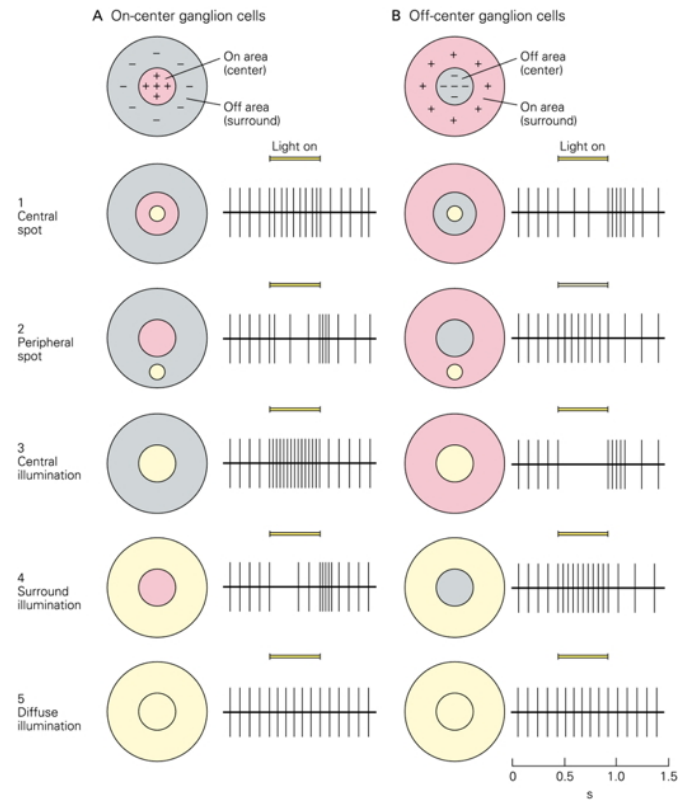

http://www.retinareference.com/anatomy/

Retinal layers

- From photoreceptors…
- To *Bipolar cells*
    - <-> and *Horizontal cells*
- To *Retinal ganglion cells*
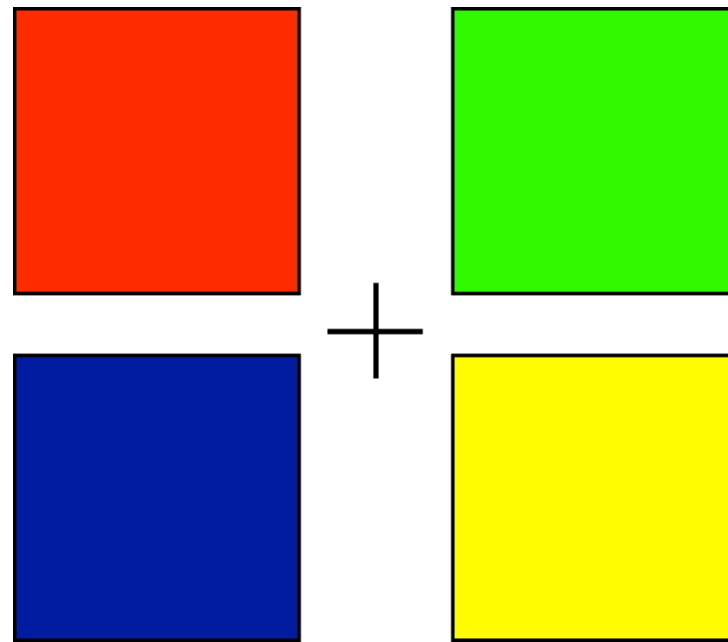   - <-> and *Amacrine cells*

Center-surround receptive fields

Center-surround receptive fields

- Center region

    - Excites (or inhibits)

- Surround region

    - Does the opposite

- Bipolar cells & Retinal Ganglion cells ->

- Most activated by "donuts" of light/dark

    - Local contrast (light/dark differences)
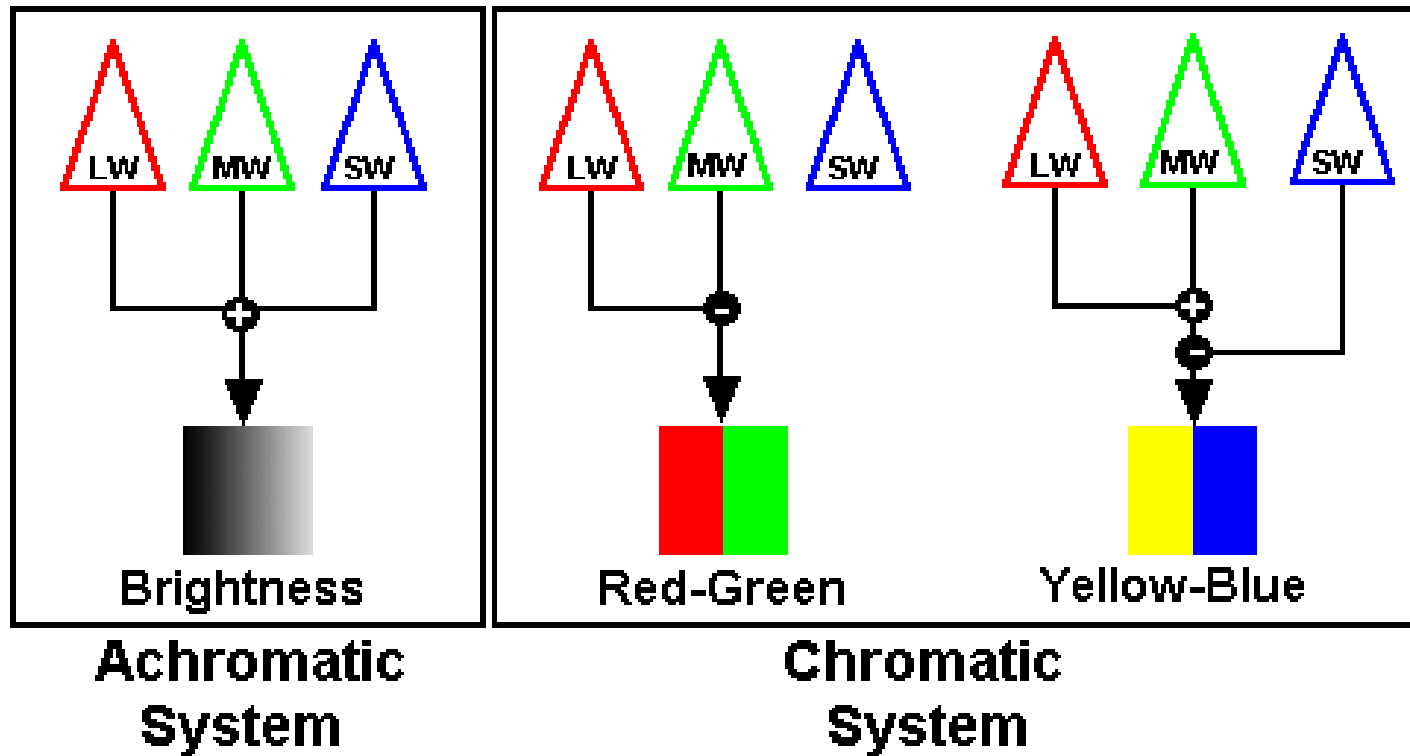
What's a reddish-green look like?

What's a reddish-green look like?

$+$

Opponent processing

Achromatic System — Brightness

Chromatic System — Red-Green, Yellow-Blue

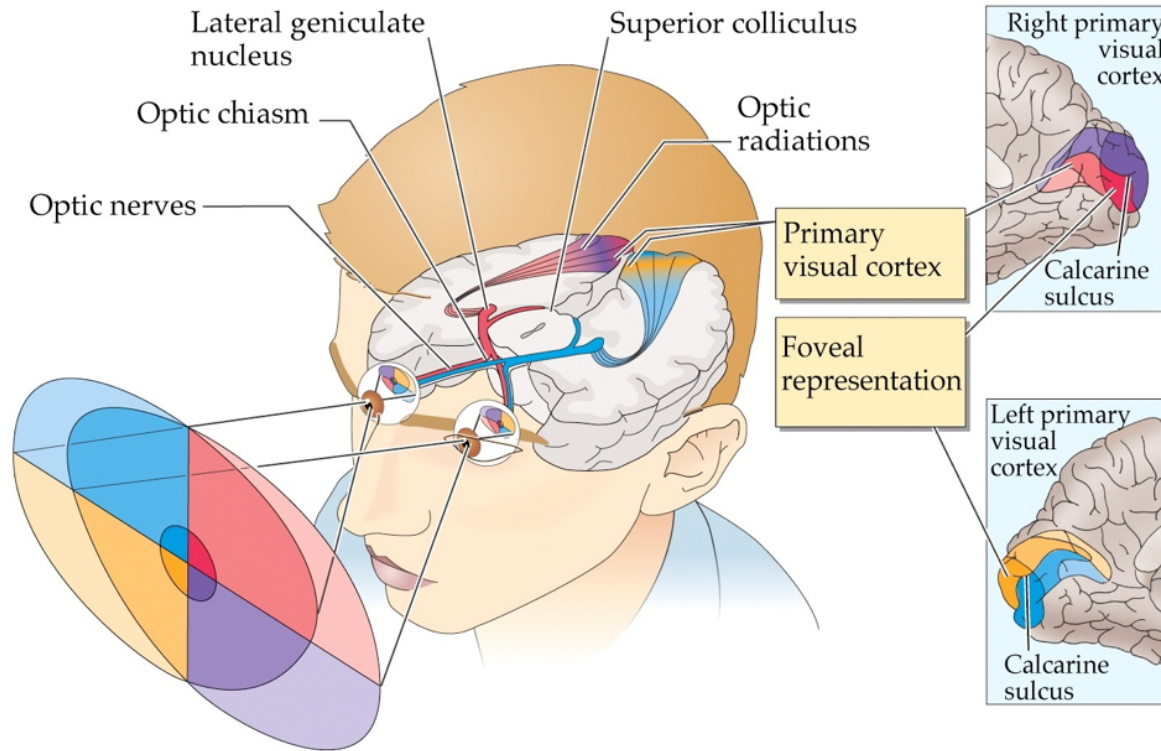http://www.visualexpert.com/sbfaqimages/RGBOpponent.gif

Opponent processing

- Black vs. white (achromatic)
- Long (red) vs. Medium (green) wavelength cones
- (Long + Medium) vs. Short cones
- Can't really see reddish-green or bluish-yellow
    - "Oppose" one another at cellular/circuit level

From eye to brain

Lateral geniculate nucleus

Superior colliculus

Optic chiasm

Optic radiations

Optic nerves

Primary visual cortex

Foveal representation

Right primary visual cortex

Calcarine sulcus

Left primary visual cortex

Calcarine sulcus

© 2001 Sinauer Associates, Inc.

From eye to brain

- Retinal ganglion cells

- 2nd/II cranial (optic) nerve

  - Optic chiasm (χ - asm): Partial crossing of fibers

  - Nasal hemiretina (lateral/peripheral visual field) cross

  - Left visual field (from L & R retinae) -> right hemisphere & vice versa

- *Lateral Geniculate Nucleus (LGN)* of thalamus (receives 90% of retinal projections)

From eye to brain

- Hypothalamus

  - *Suprachiasmatic nucleus* (superior to the optic chiasm): Synchronizes day/night cycle with circadian rhythms
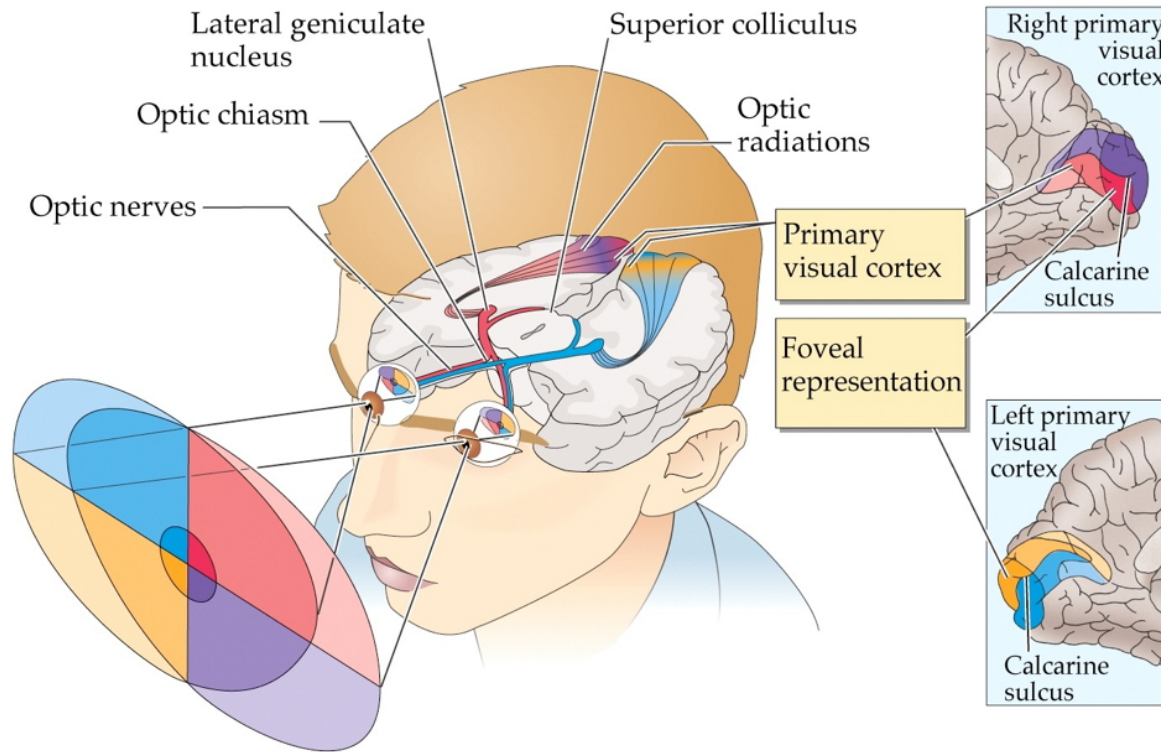
- Superior colliculus & brainstem

LGN

Level of section:

Thalamus

6
5
4
3
2
1
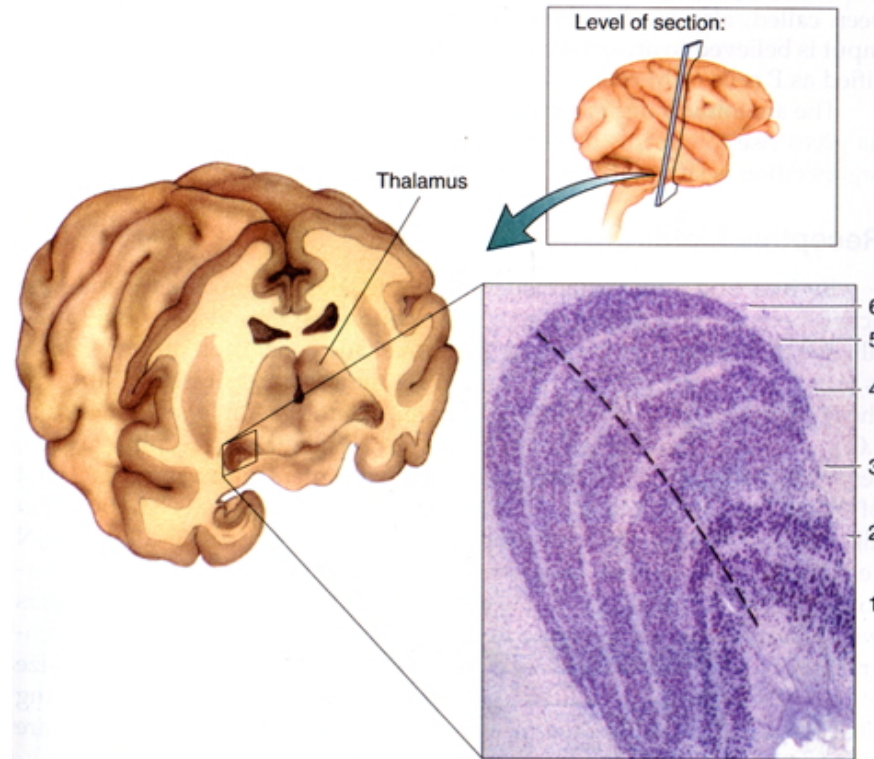
LGN

- 6 layers + intralaminar zone

    - Parvocellular (small cells): chromatic

    - Magnocellular (big cells): achromatic

    - Koniocellular (chromatic - short wavelength?)

- Retinotopic map of opposite visual field

From LGN to V1

Lateral geniculate nucleus

Optic chiasm

Optic nerves

Superior colliculus

Optic radiations

Primary visual cortex

Foveal representation

Right primary visual cortex

Calcarine sulcus

Left primary visual cortex

Calcarine sulcus
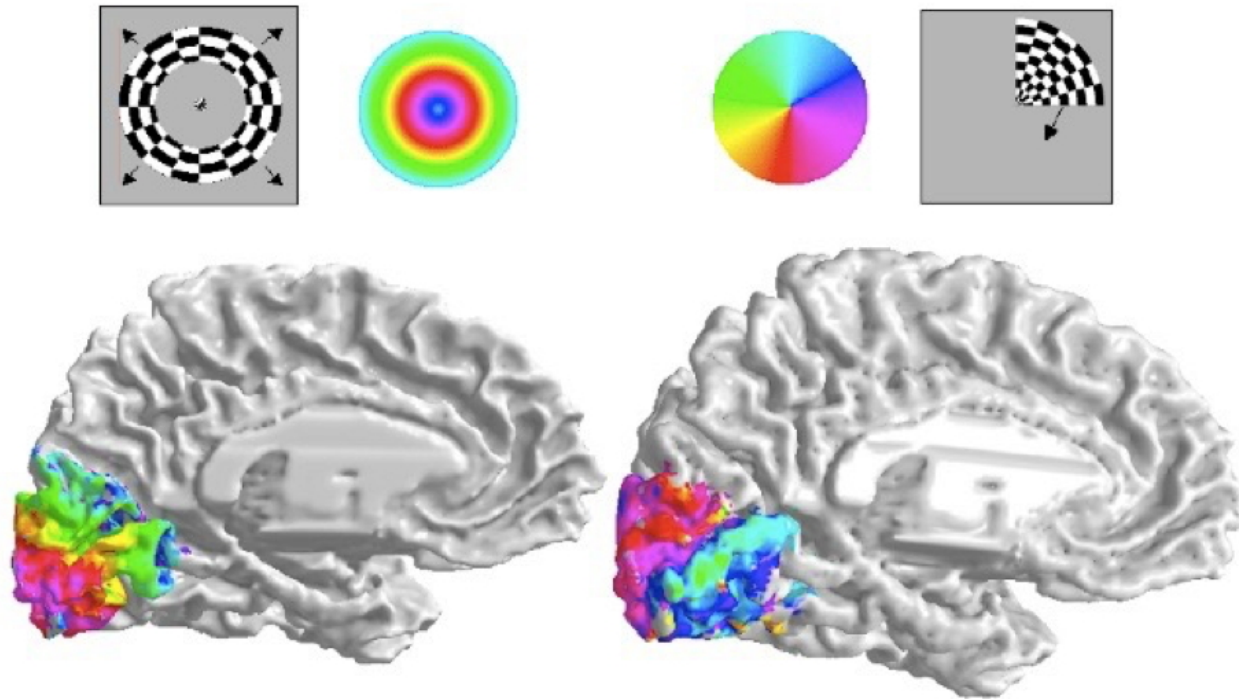
© 2001 Sinauer Associates, Inc.

From LGN to V1

- Via *optic radiations*

- *Primary visual cortex (V1)* in occipital lobe

- Create "stria of Gennari" (visible stripe in layer 4)

- Calcarine fissure (medial occiptal lobe) divides lower/upper visual field

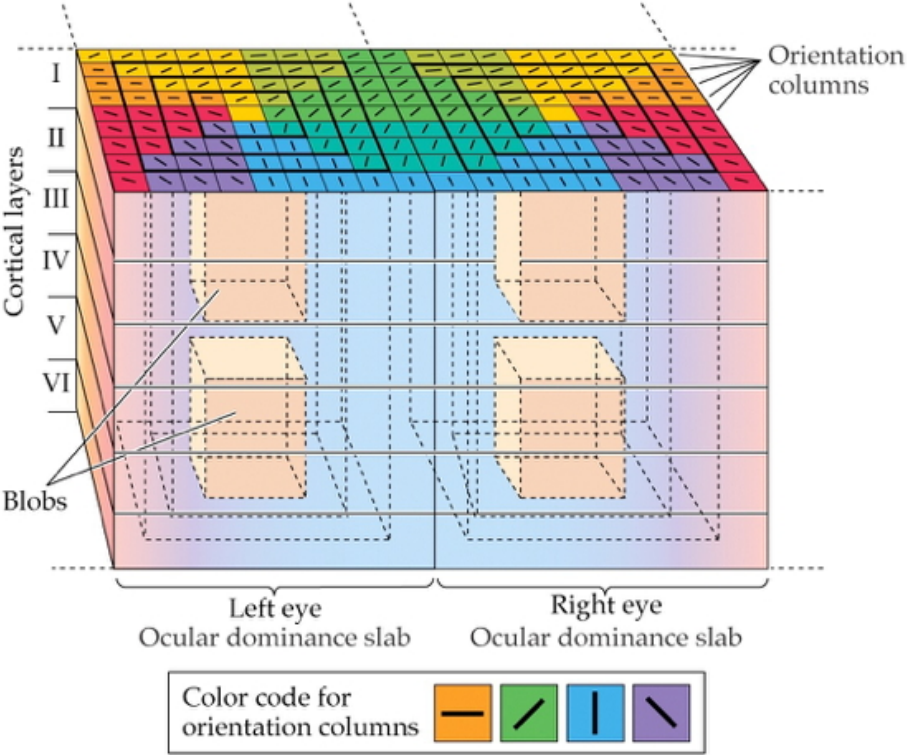# Human V1
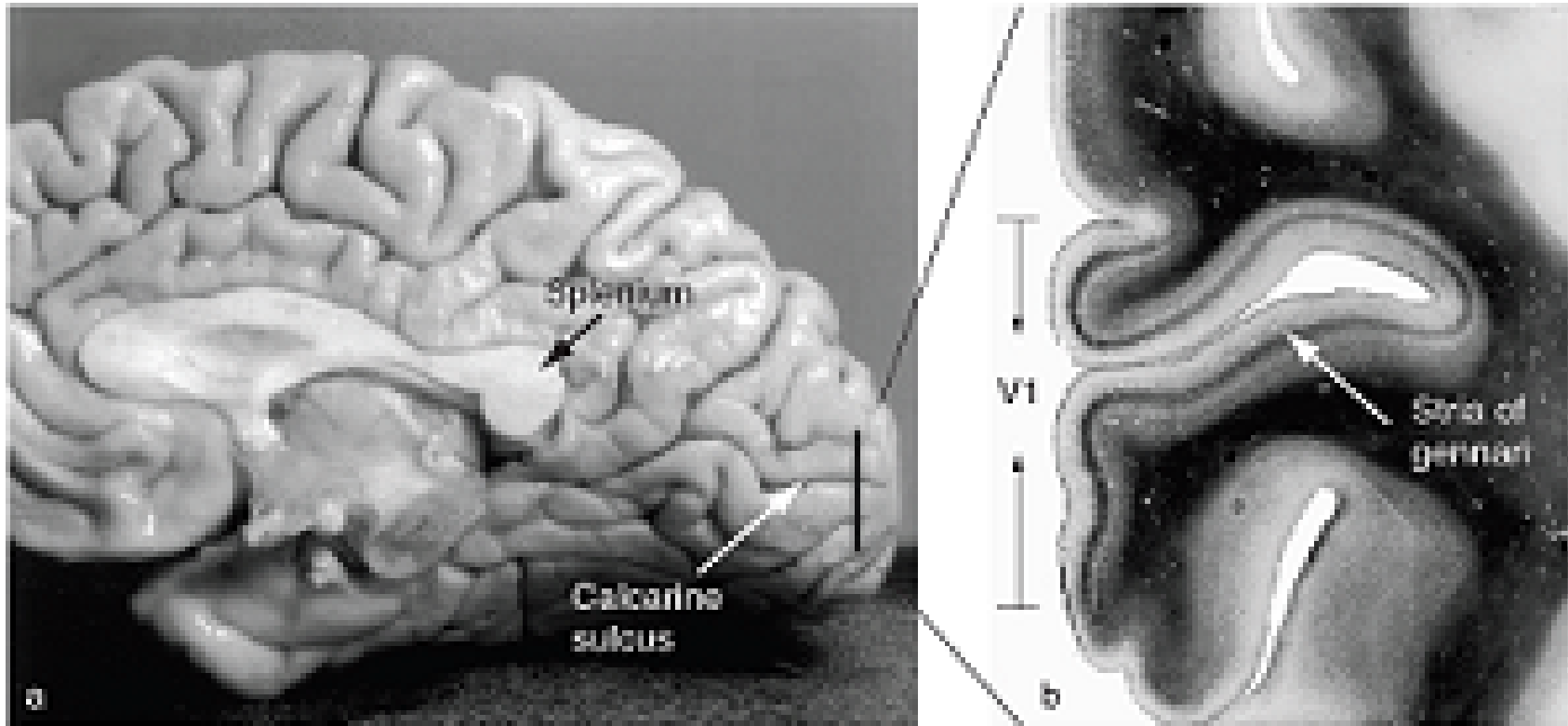
Measuring retinotopy in V1

(Dougherty et al., 2003)

Retinotopy in V1

- Fovea overrepresented

    - Analogous to somatosensation

    - High acuity in fovea vs. lower outside it

- Upper visual field/lower (ventral) V1 and *vice versa*

V1 has laminar, columnar organization

V1 has laminar, columnar organization

- 6 laminae (layers)

  - Input: Layer 4 (remember stria of Gennari?)

  - Output: Layers 2-3 (to cortex), 5 (to brainstem), 6 (to LGN)
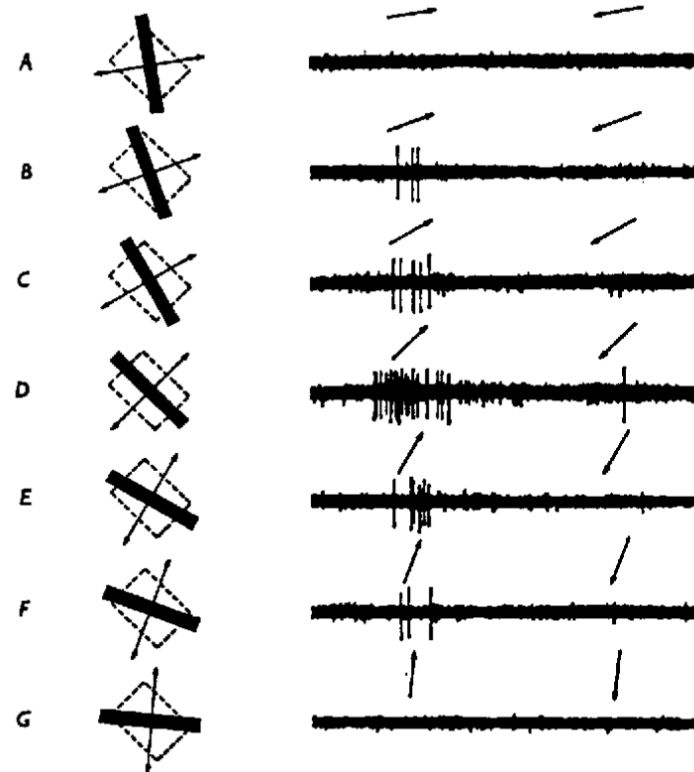
V1 has laminar, columnar organization

- Columns
  - Orientation/angle
  - Spatial frequency

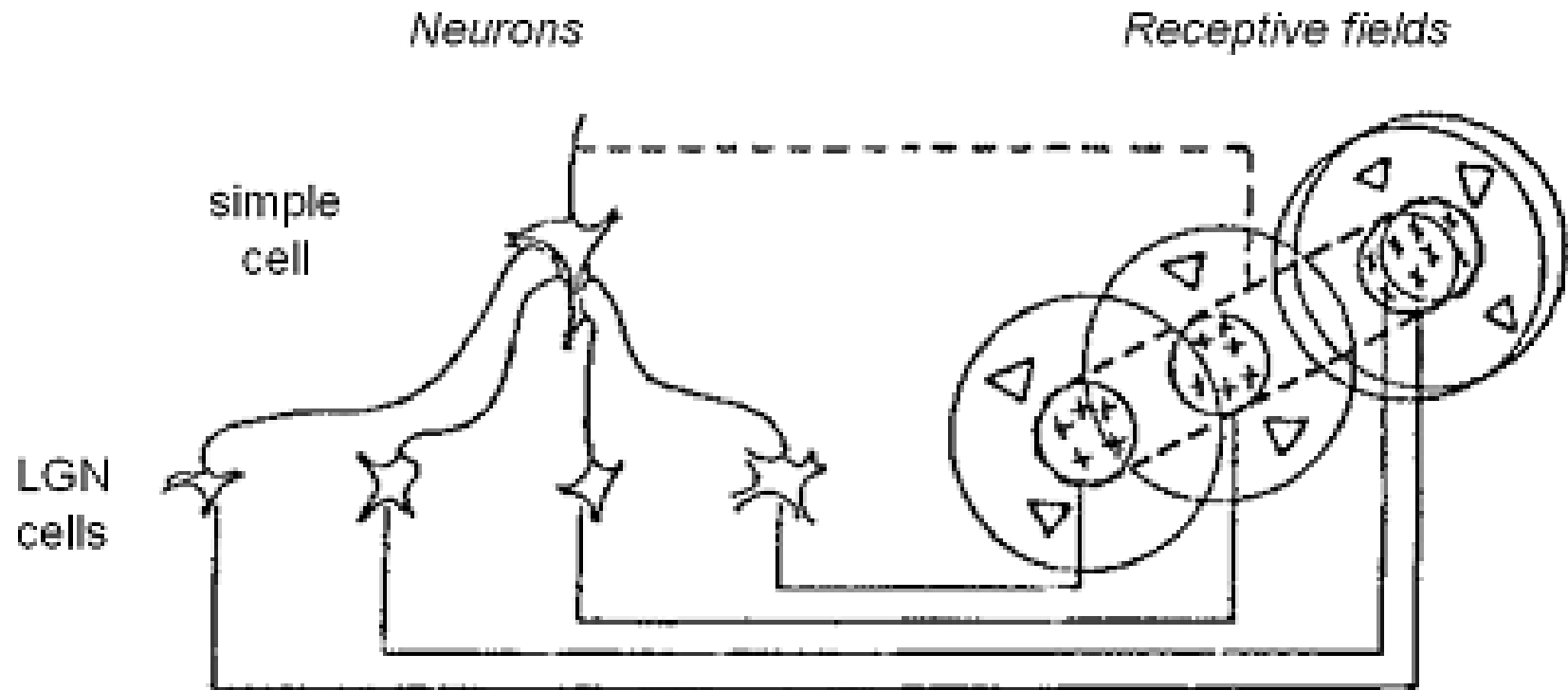# The "accidental" discovery of oriented receptive fields in V1
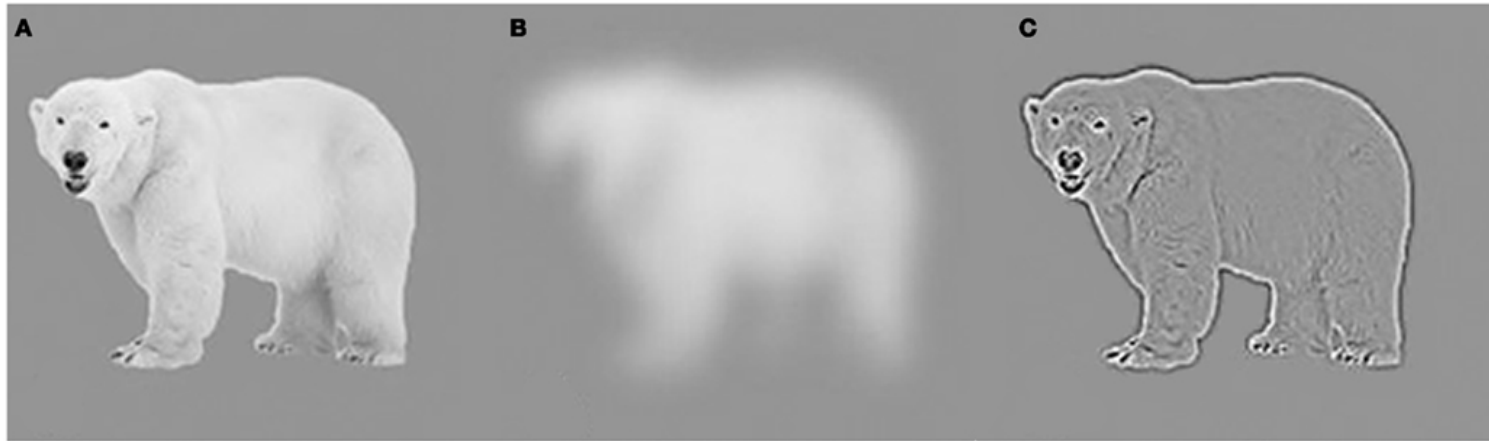
Orientation/angle tuning

https://foundationsofvision.stanford.edu/wp-content/uploads/2012/02/dir.selective.png

From center-surround receptive fields to line detection

Neurons

Receptive fields

simple
cell

LGN
cells

Spatial frequency tuning

Low == gist || high == details
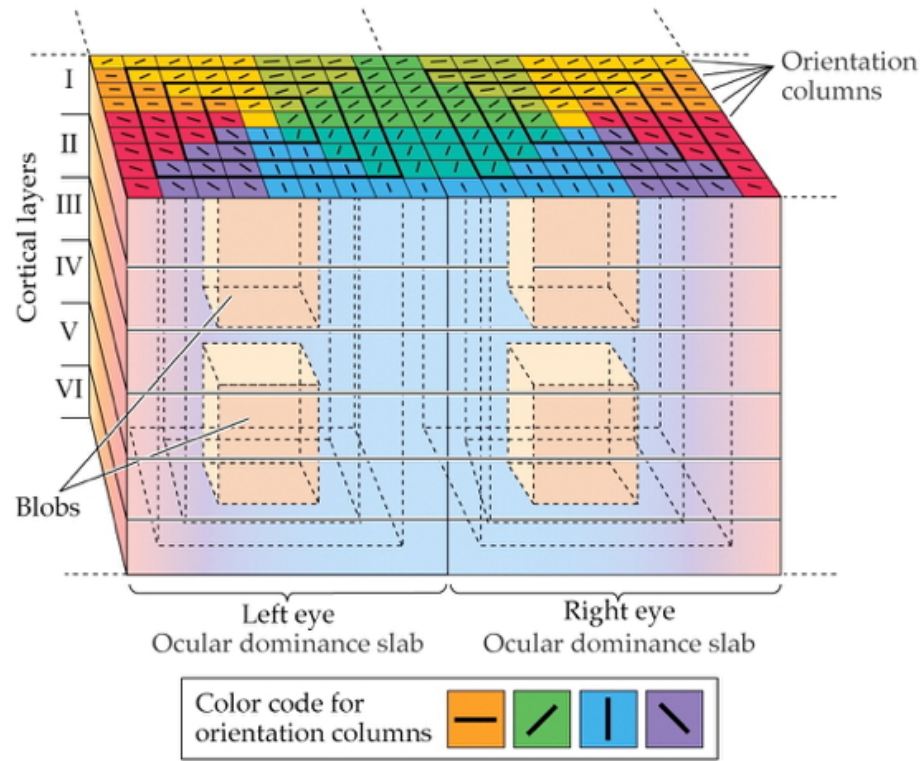

(Panichello, Cheung, & Bar, 2013)

V1 has laminar, columnar organization

- Columns
  - Color/wavelength
  - Eye of origin, *ocular dominance*

Ocular dominance columns

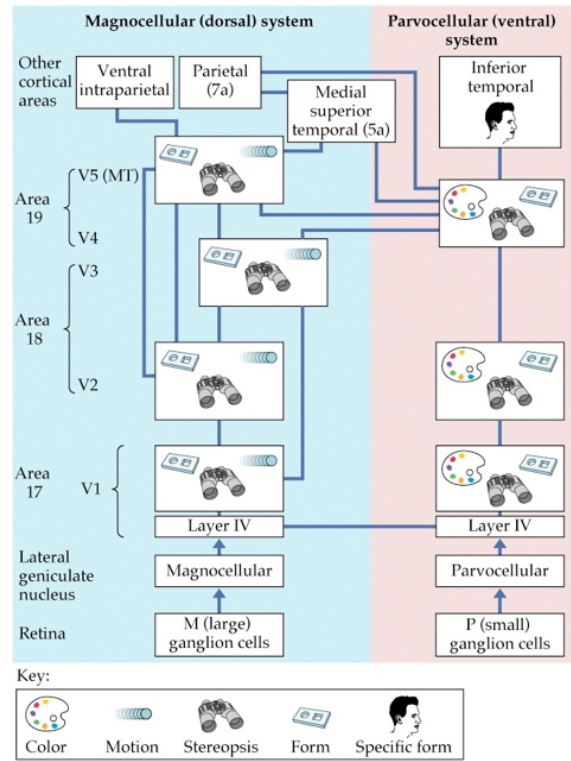# Ocular dominance signals retinal disparity

http://www.scholarpedia.org/w/images/9/99/11-Hubel-Wiesel-model.png

Beyond V1

Beyond V1

- Larger, more complex receptive fields
- *Dorsal stream* (where/how)
    - Toward parietal lobe
- *Ventral stream* (what)

What is vision for?

- What is it? (form perception)

- Where is it? (space perception)

- How do I get from here to there (action control)

- What time (or time of year) is it?

The Real Reason for Brains

The neuroscience of action

- What types of actions are there?

- How are they produced?

  - By the muscles

  - By the nervous system

Remember

- Nervous system "output" includes

  - Movements

  - Autonomic responses

  - Endocrine responses

Types of actions

http://www.kidport.com/reflib/science/humanbody/muscularsystem/image
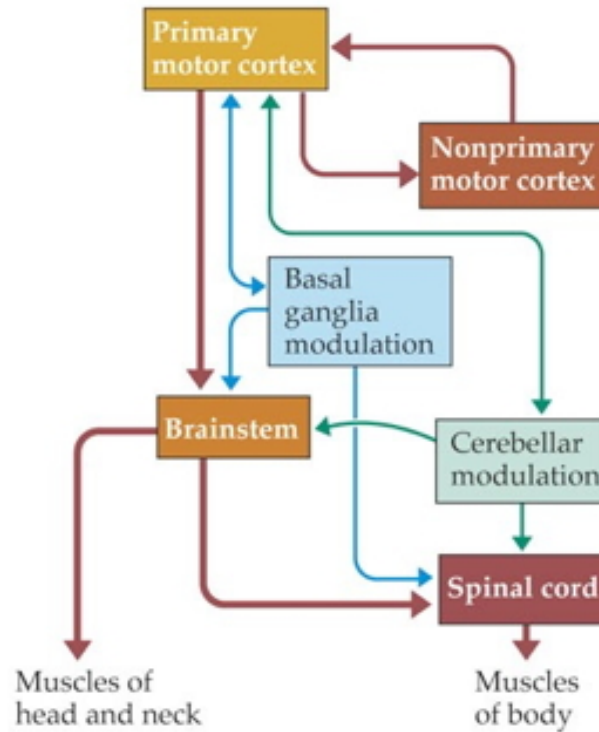
Types of actions

- Reflexes
    - Simple, highly stereotyped, unlearned, rapid
- vs. Planned or voluntary actions
    - Complex, flexible, acquired, slower
- Discrete (reaching) vs. rhythmic (walking)
- Ballistic (no feedback) vs. controlled (feedback)

Multiple, parallel controllers

Primary motor cortex

Nonprimary motor cortex

Basal ganglia modulation

Brainstem

Cerebellar modulation

Spinal cord

Muscles of head and neck

Muscles of body

BIOLOGICAL PSYCHOLOGY, Fourth Edition, Figure 11.4 © 2004 Sinauer Associates, Inc.

Key "nodes" in network

- Primary motor cortex (M1)

- Non-primary motor cortex

- Basal ganglia

- Brain stem

- Cerebellum

- Spinal cord

Muscle classes

- Axial

    - Trunk, neck, hips

- Proximal

    - Shoulder/elbow, pelvis/knee

- Distal

    - Hands/fingers, feet/toes

Muscles

http://mypages.valdosta.edu/dodrobin/2651/Muscles/Muscles.jpg
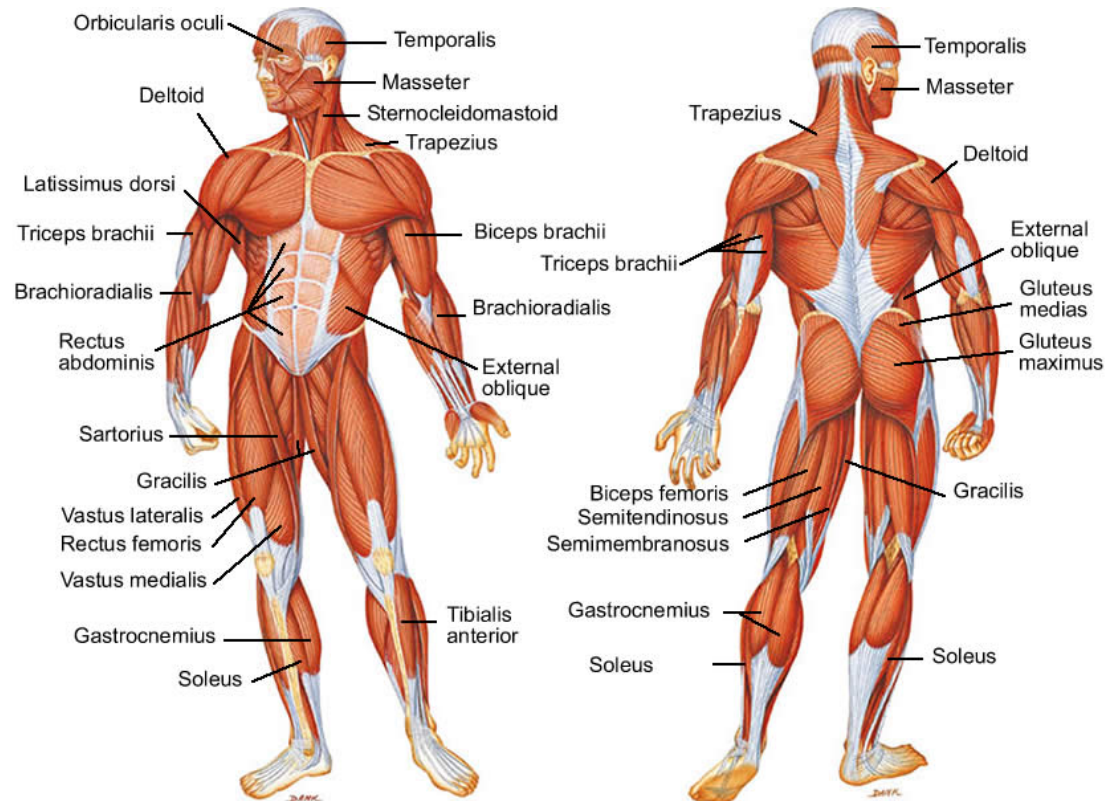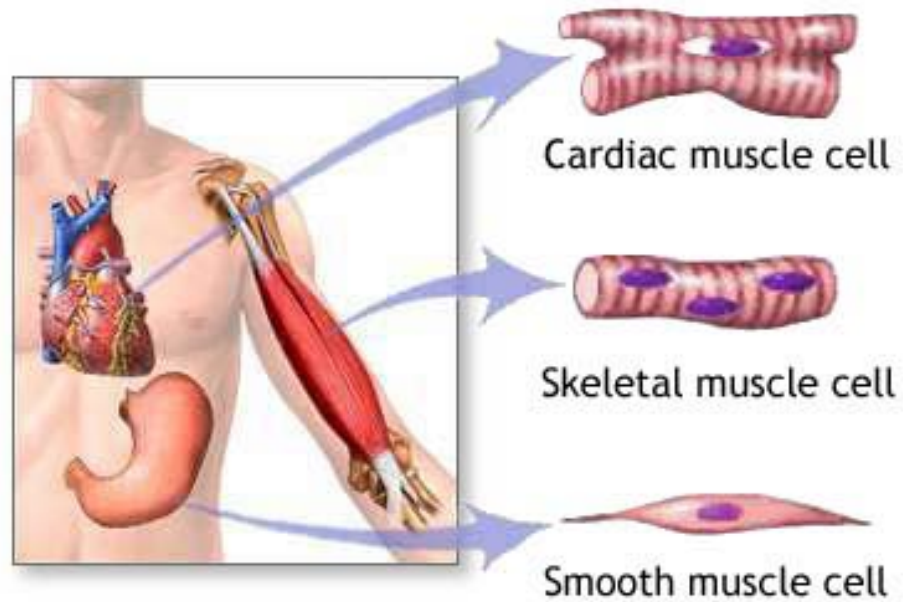
Muscle types

- Smooth

    - Arteries, hair follicles, uterus, intestines

    - Regulated by ANS (involuntary)

- Striated (striped)

    - Skeletal

    - Voluntary control, mostly connected to tendons and bones
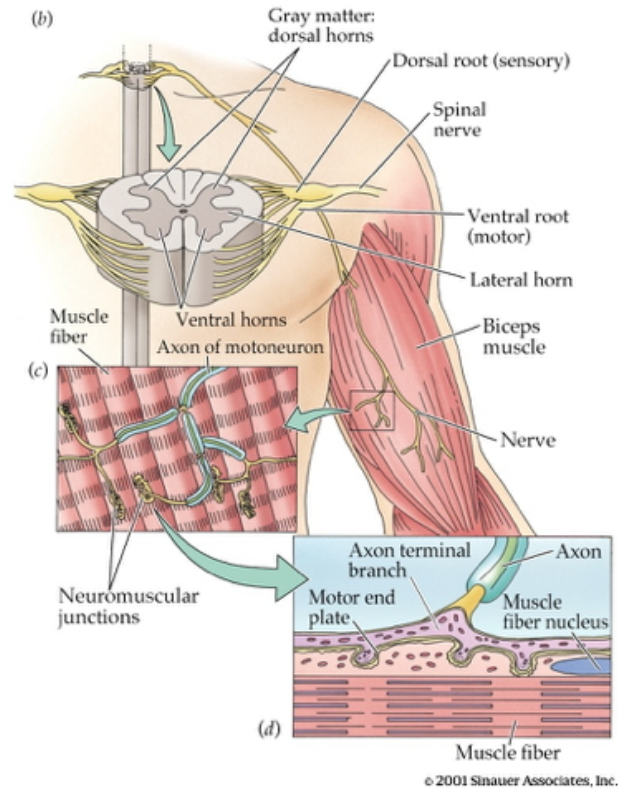
- Cardiac

Muscle types

Cardiac muscle cell

Skeletal muscle cell

Smooth muscle cell

© ADAM, Inc.

http://graphics8.nytimes.com/images/2007/08/01/health/adam/19917.jpg

How skeletal muscles contract

- Motoneuron (ventral horn of spinal cord)
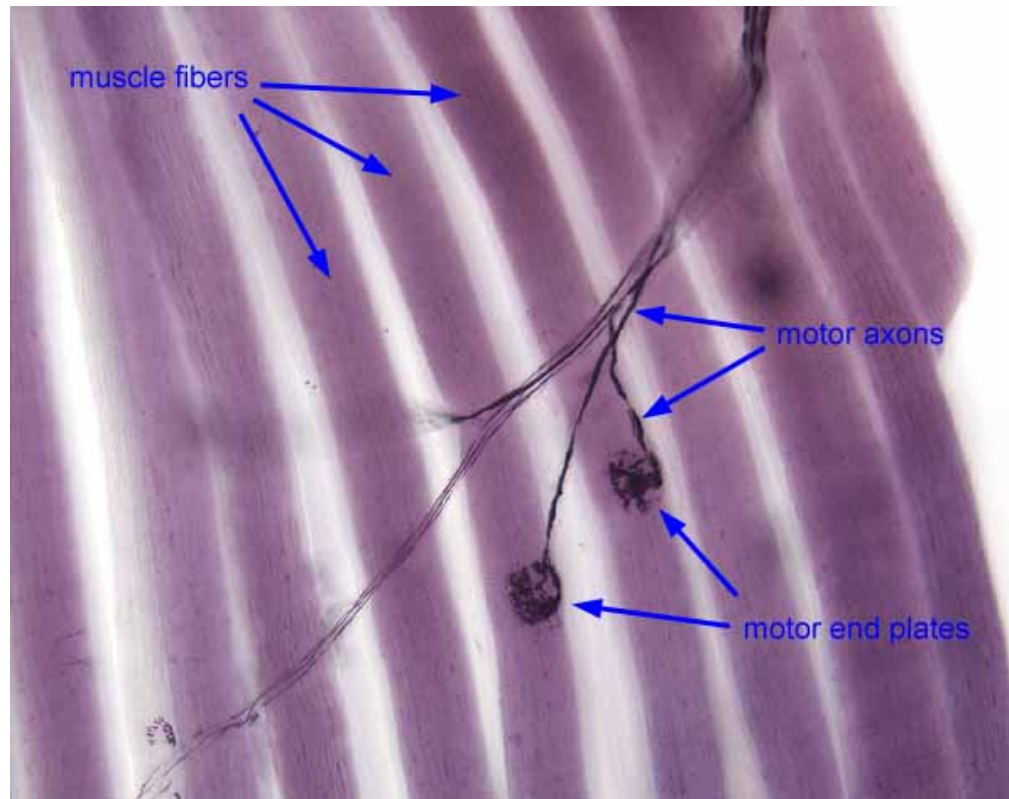- Neuromuscular junction
    - Releases ACh

From spinal cord to muscle

How skeletal muscles contract

- Motor endplate
    - Nicotinic ACh receptor
- Excitatory endplate potential
    - Muscle fibers depolarize
    - Depolarization spreads along fibers like an action potential
    - Sarcomeres are segments of fibers
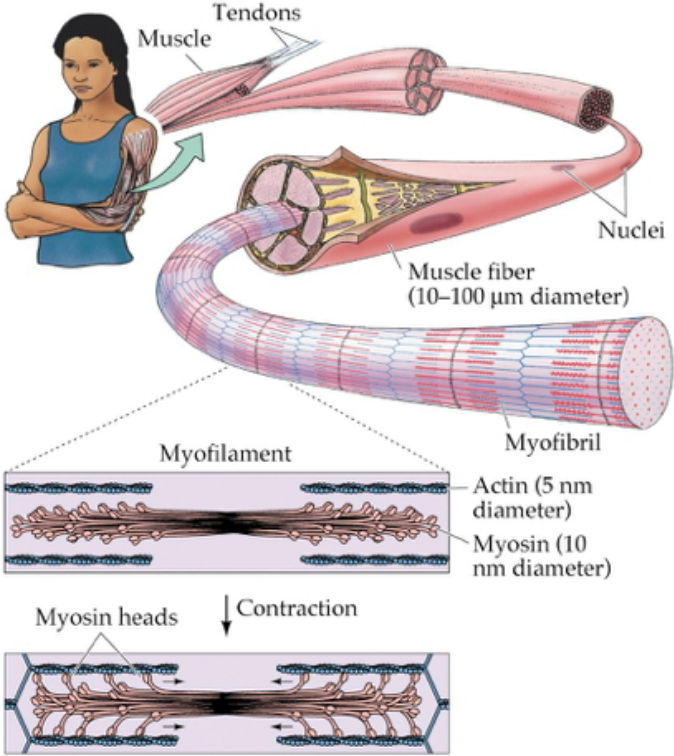   - Intramuscular stores release Ca++

Motor endplate

How skeletal muscles contract
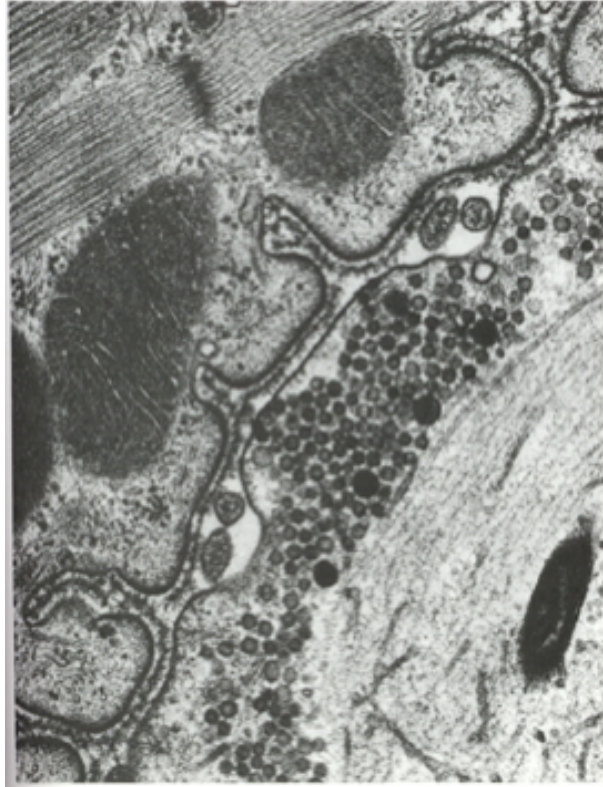
- Myofibrils (w/in sarcomere)

  - Actin & mysosin proteins

  - "Molecular gears"

- Bind, move, unbind in presence of Ca++, ATP

Anatomy of muscle fibers

Tendons
Muscle
Nuclei
Muscle fiber (10–100 μm diameter)
Myofibril
Myofilament
Actin (5 nm diameter)
Myosin (10 nm diameter)
Myosin heads
Contraction

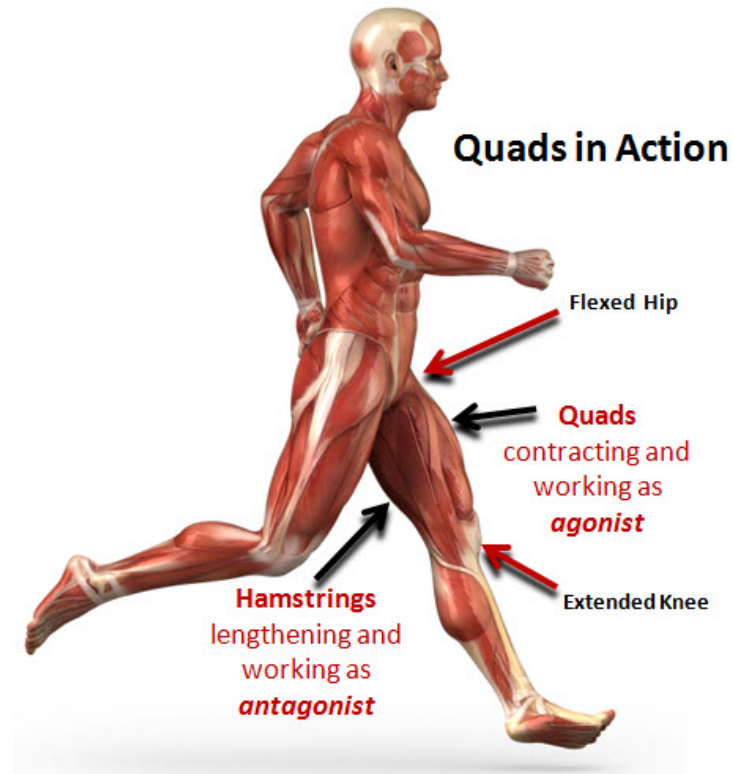© 2001 Sinauer Associates, Inc.

Anatomy of motor endplate

Muscle contraction

Agonist/antagonist muscle pairs

http://2.bp.blogspot.com/-TpOC4my_NBc/T0J-MhEv29I/AAAAAAAAF88/dYLv7QzFwmg/s1600/Hamstring-Quad4.jpg

Meat preference?

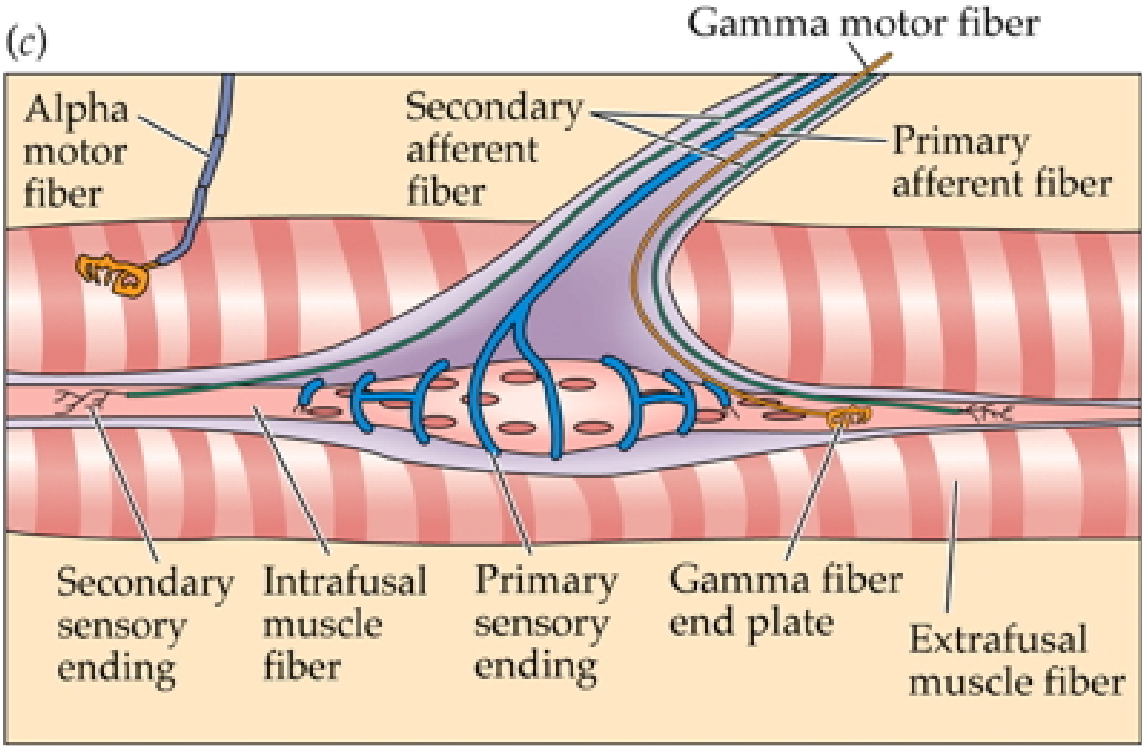# Muscle fiber types

- Fast twitch/fatiguing

    - Type II

    - White meat

- Slow twitch/fatiguing

    - Type I

    - Red meat

Muscles are sensory organs, too!

© Can Stock Photo

Two muscle fiber types

(c)

Alpha motor fiber

Secondary afferent fiber

Gamma motor fiber

Primary afferent fiber

Secondary sensory ending

Intrafusal muscle fiber

Primary sensory ending

Gamma fiber end plate

Extrafusal muscle fiber

© 2001 Sinauer Associates, Inc.

Two muscle fiber types

- *Intrafusal* fibers

    - Sense length/tension

    - Contain muscle spindles linked to Ia afferents

    - ennervated by gamma (γ) motor neurons

- *Extrafusal* fibers

    - Generate force

    - ennervated by alpha (α) motor neurons

Next time…

- More on action

References

Dougherty, R. F., Koch, V. M., Brewer, A. A., Fischer, B., Modersitzki, J., & Wandell, B. A. (2003). Visual field representations and locations of visual areas V1/2/3 in human visual cortex. *Journal of Vision*, *3*(10), 1–1. https://doi.org/10.1167/3.10.1

Panichello, M. F., Cheung, O. S., & Bar, M. (2013). Predictive feedback and conscious visual experience. *Perception Science*, *3*, 620. https://doi.org/10.3389/fpsyg.2012.00620