Institute of Neuroinformatics
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Computation in Neural Systems: Biological Vision

<u>17.5.2018</u>

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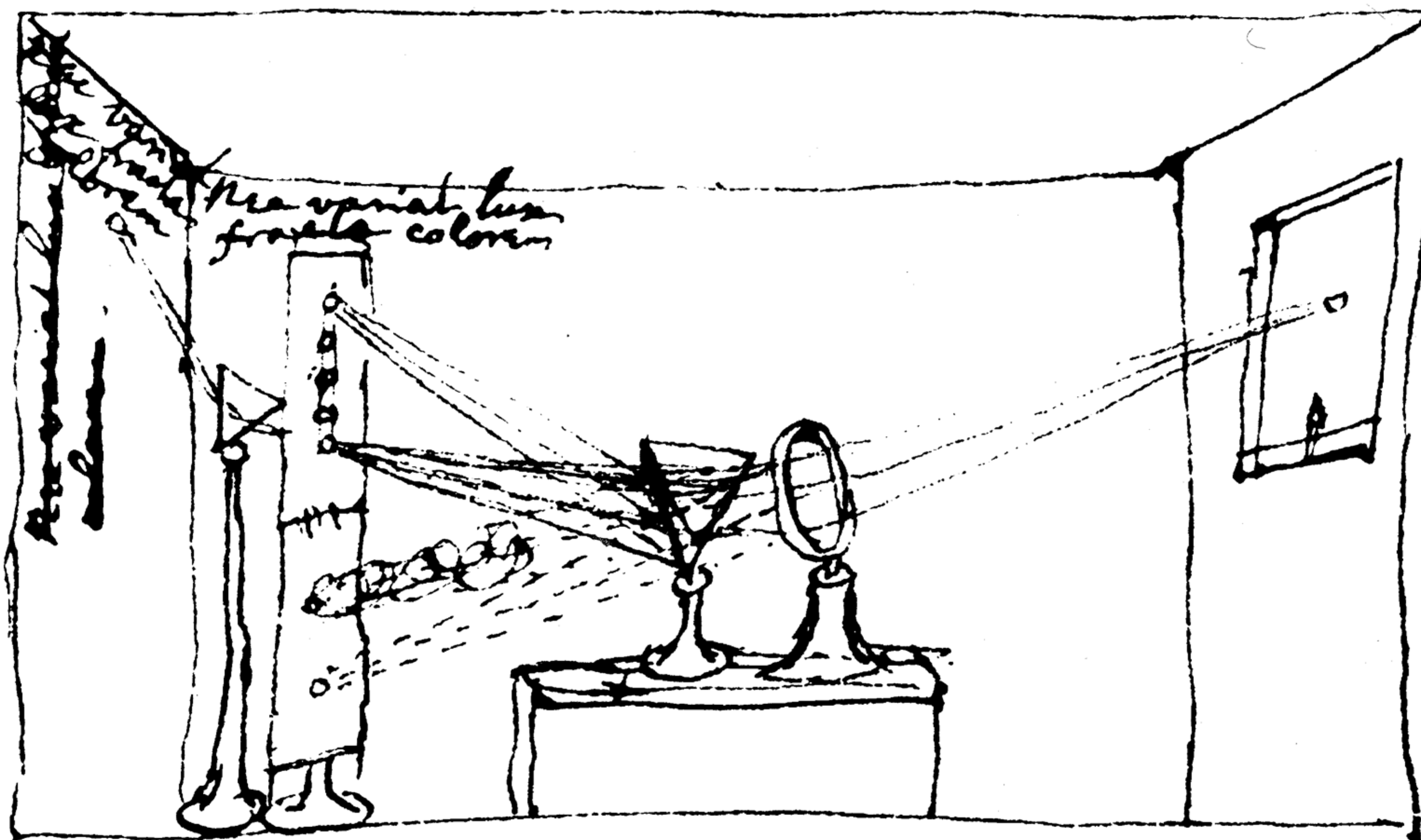
www.ini.unizh.ch/~kiper/comp_vis/index.html

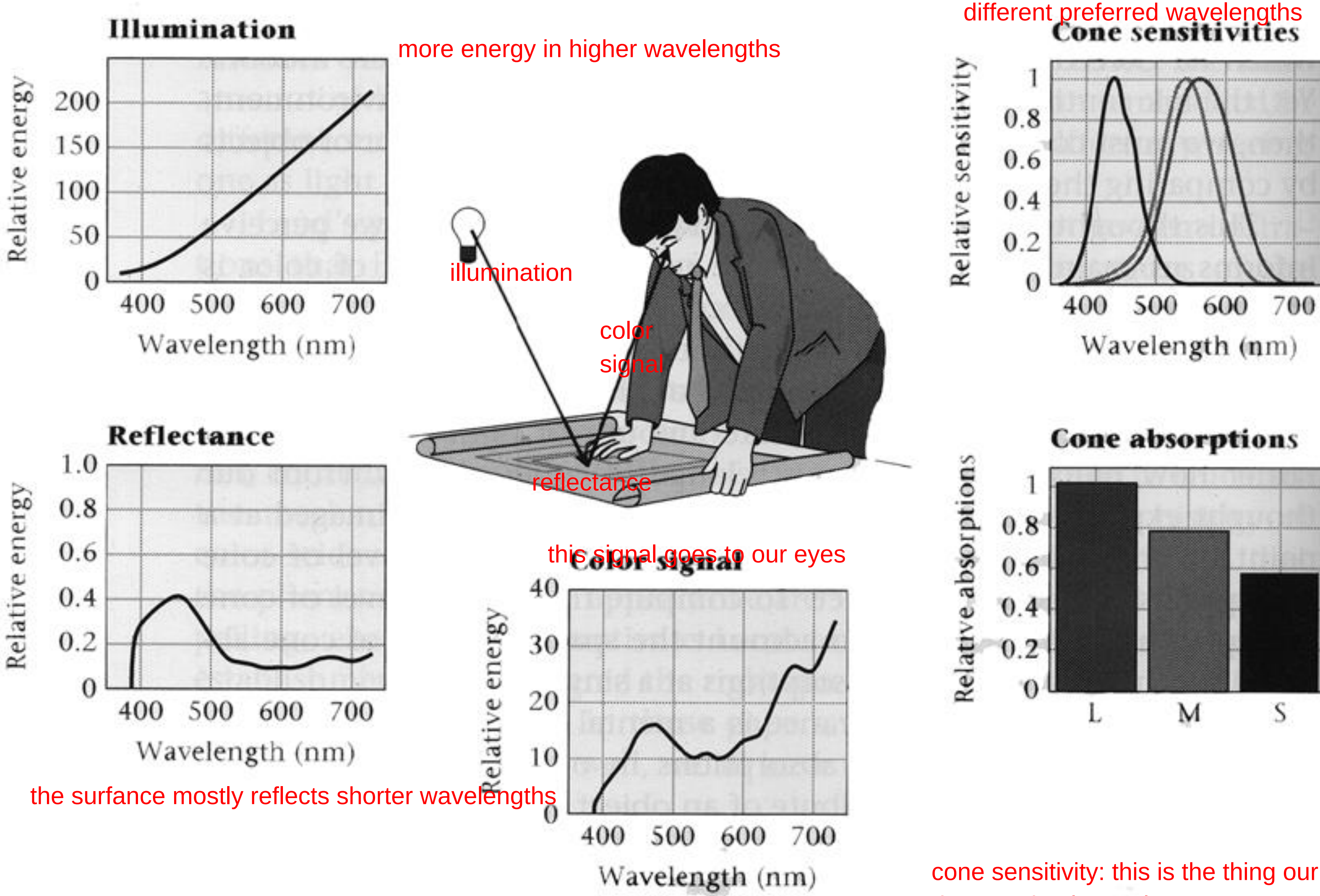
Newton's experiment



color vision evolution: it helps to distinguish fruits that are raw, or in the forest and so on. It's a big advantage for us. nowadays, for our purposes, color is not crucial anymore for all the tasks we need to do.

Wandell, 1998, plate 4.1

Real life color perception



cones got different sensitivities - they filter the signal and are excited by different preferred wavelengths

more energy in higher wavelengths

this signal goes to our eyes

the surfance mostly reflects shorter wavelengths

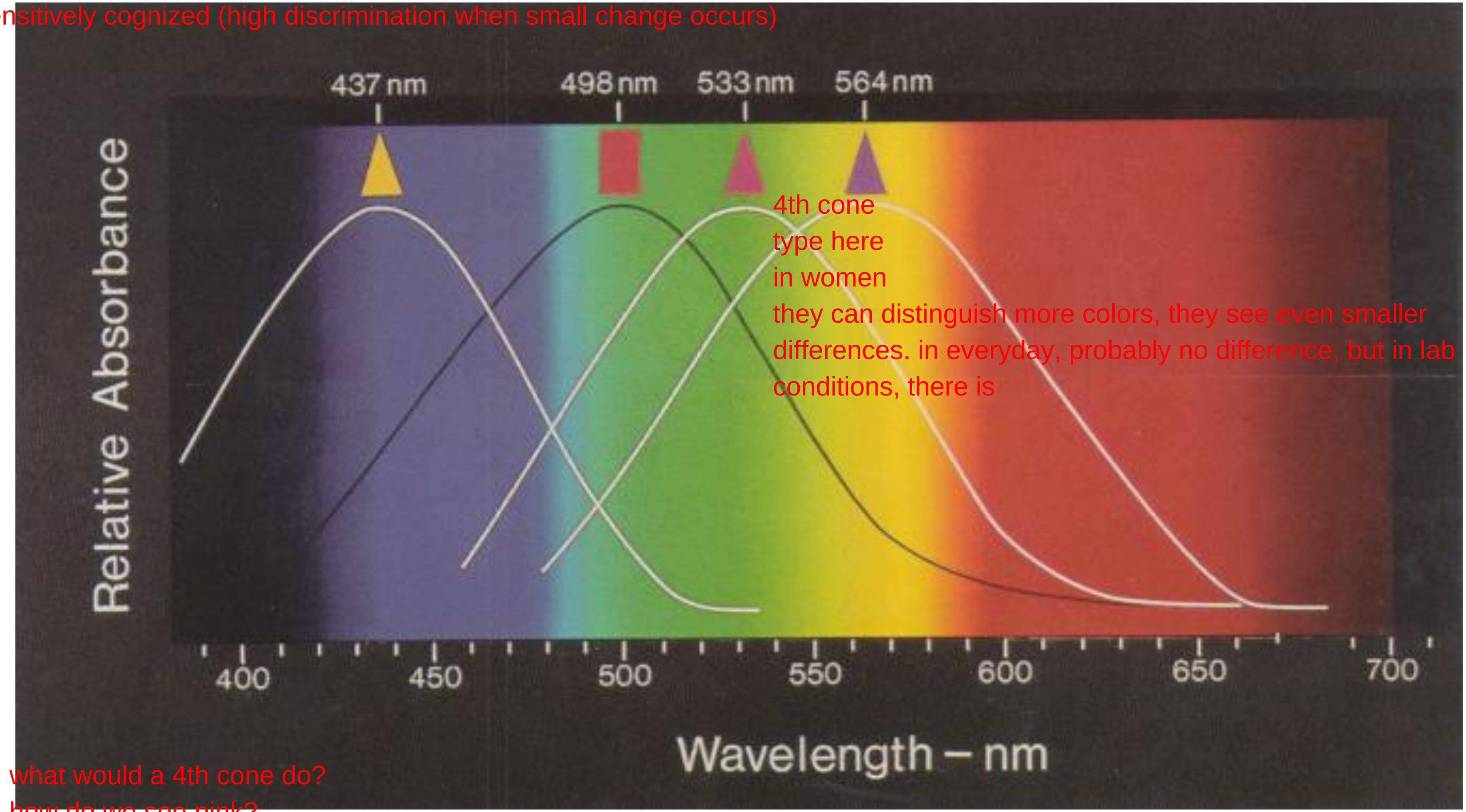
cone sensitivity: this is the thing our brain does to simulate colors

for rods it's irrelevant - when enough light, rods are saturated and S,M,L are important
on rods, no color vision. ofc they are wavelength selective, since they dont respond to ultraviolet etc.
rods are about as selective as cones
to distinguish wavelengths and see color therefore, we need to compare cones
we need at least two photoreceptors to distinguish color. 3 allow us to distinguish even more and better

Photoreceptors sensitivity profiles

color discrimination ability not the same for all wavelengths:
green, blue, yellow, red are unique colors: they occur without the others being a small component of them. changes there are very sensitively cognized (high discrimination when small change occurs)

S Rods M L



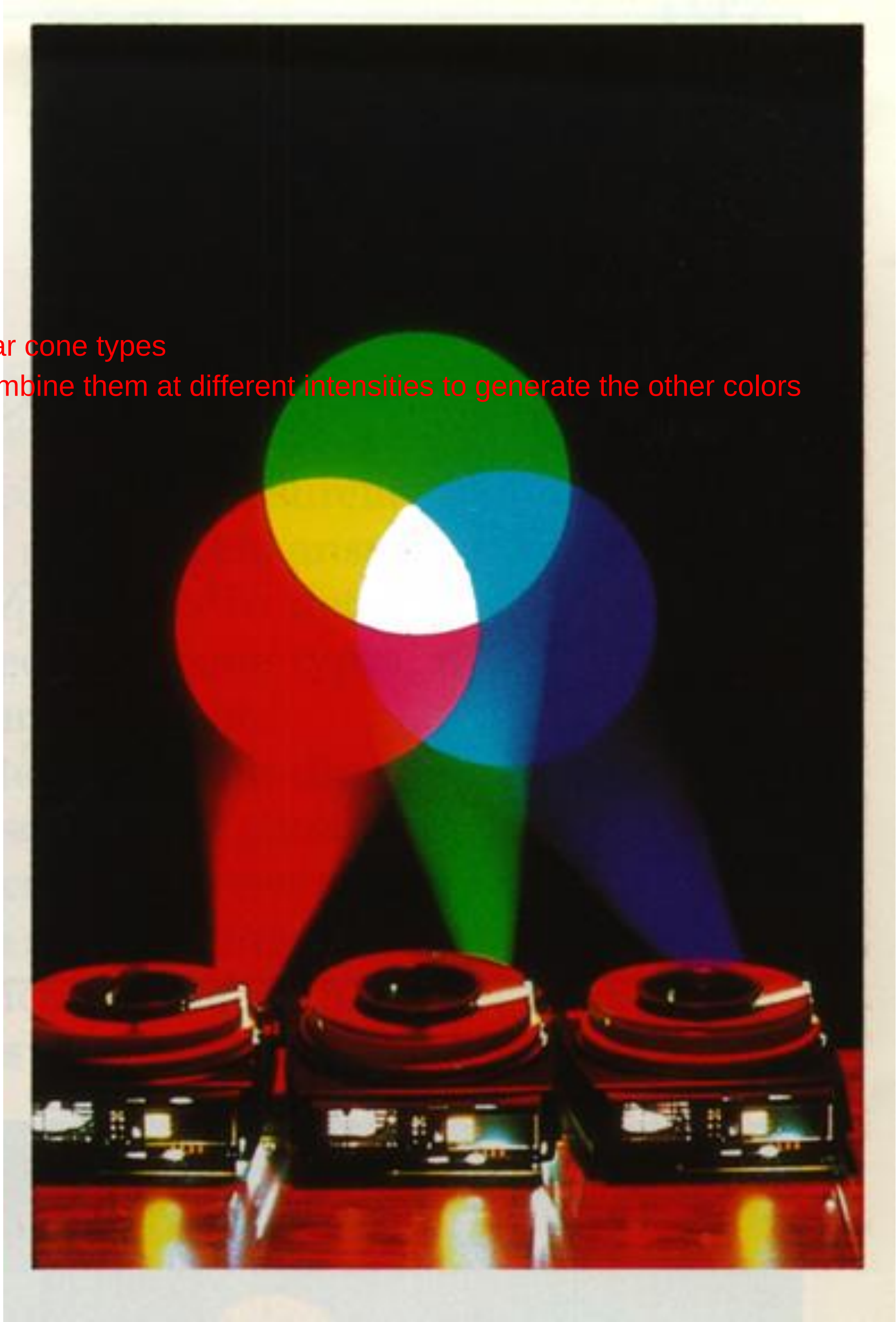
4th cone type here in women
they can distinguish more colors, they see even smaller differences. in everyday, probably no difference, but in lab conditions, there is

what would a 4th cone do?
how do we see pink?

Dowling, 1987 (Plate 8)

rhodopsin: at outer segment of
photoreceptors

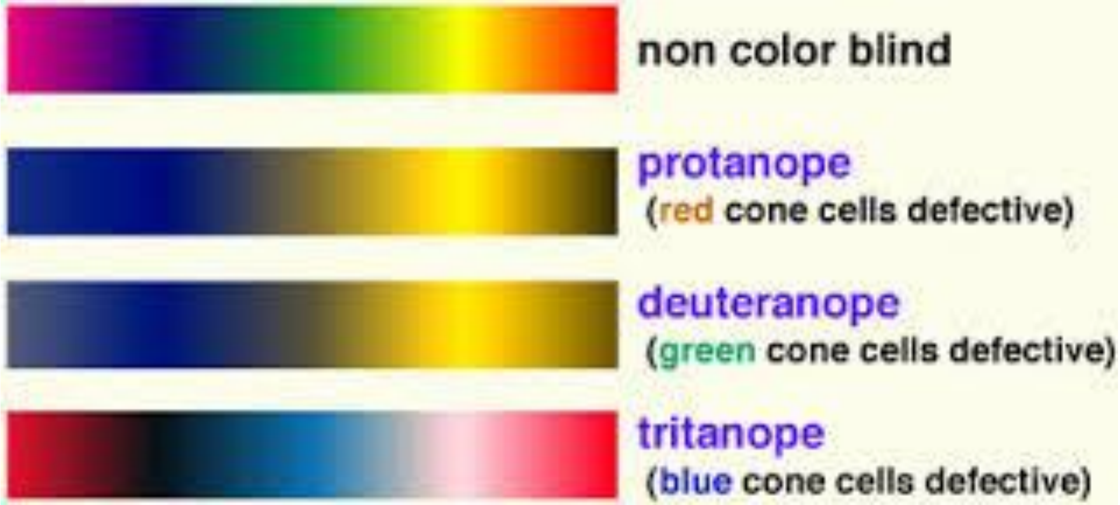
trichromatic: activity of 3 particular cone types
we only need 3 primaries and combine them at different intensities to generate the other colors



Sekuler and Blake, 1985, plate 6

more prevalent in males than females - pigments located on x-chromosome
10% of males have a problem distinguishing color

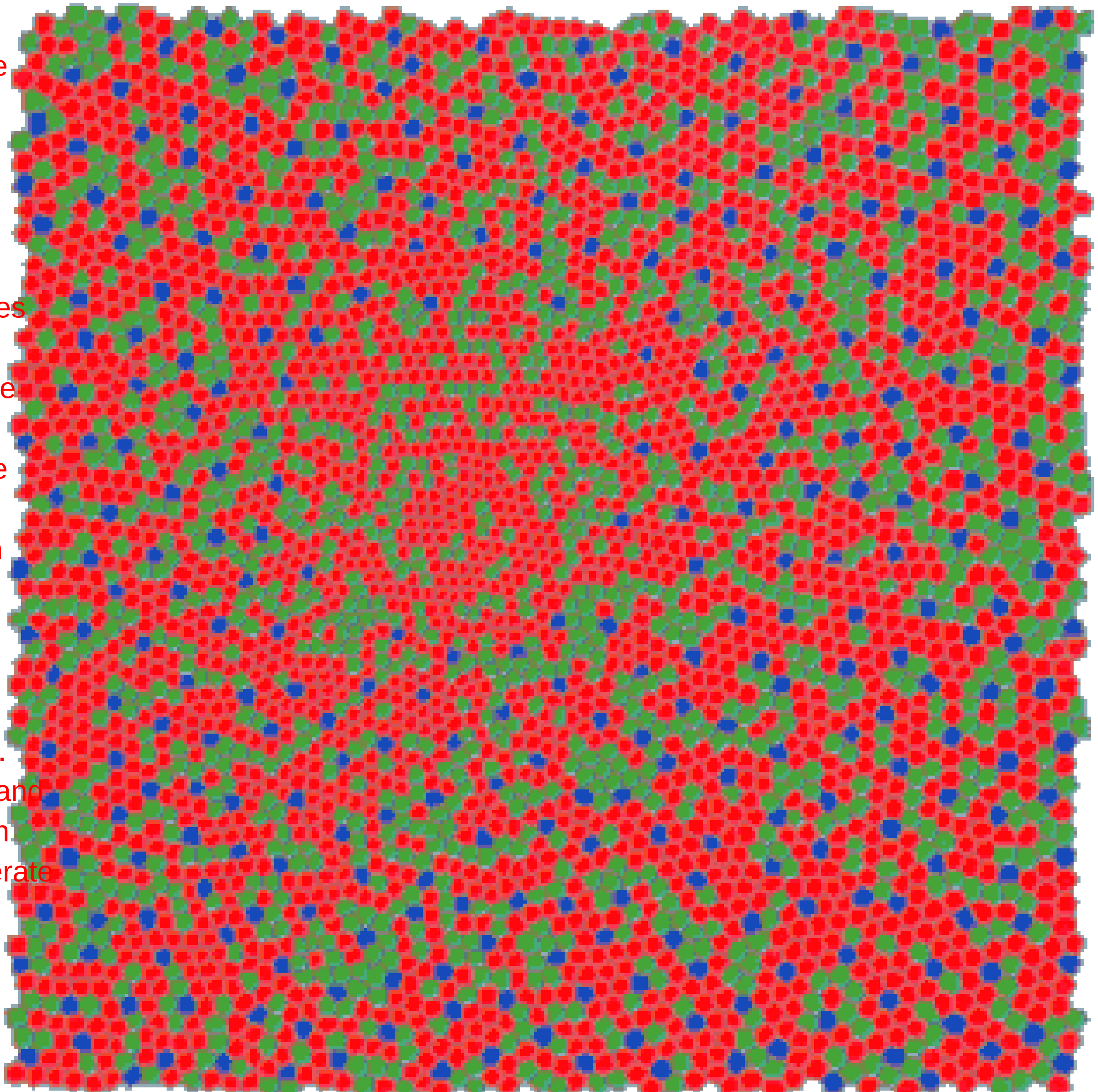
similar since cones types are close



some color vision problems are due to cortical lesions like in the temporal pw (cerebral achromatoxia) - not all color porblems are due to photoreceptor/pigment fails

Cone mosaic

faithful reproduction of cone distrubtion on retina:
more red and green, less blue. spacing much larger,
red is most denselx packed in the middle of fovea,
we dont have any blue cones
center of fovea: foveala
in the center of fovea we are dichromatic. in this regions we dont see as much as we can in the rest of the fovea.
here we optimize resolution so its highest in the center of fovea.



humans can stimulate individual cones in humans. (when only one is affected and not its neighbours: do it with lasers, so that we can generate such a map)

different people have differnet ratios of distribtution.
but these humans see all the same color vision.
so the actual density does not really matter. as long as we have some (must be more than threshold), we see colors. also, adaptation is possible.

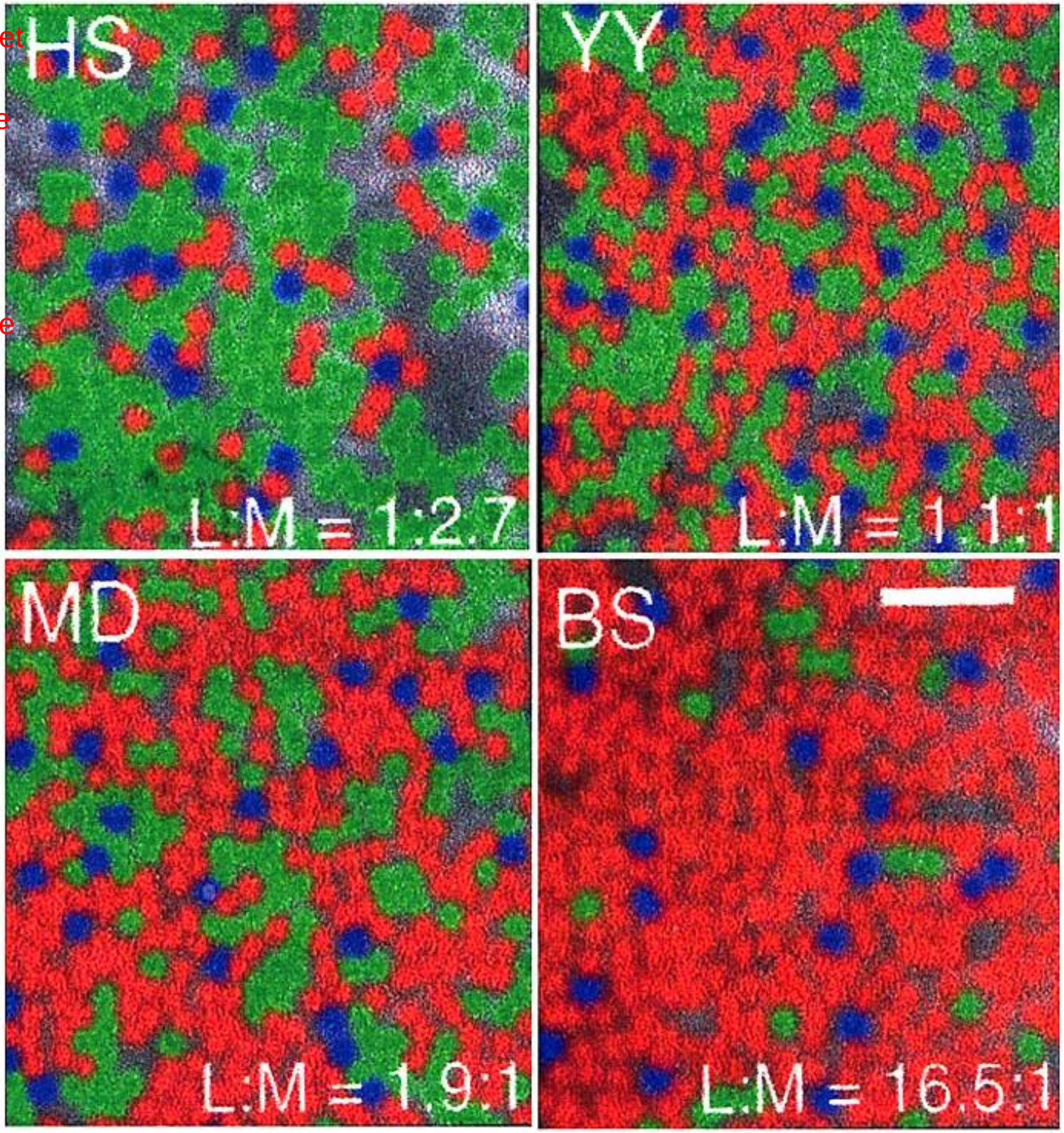
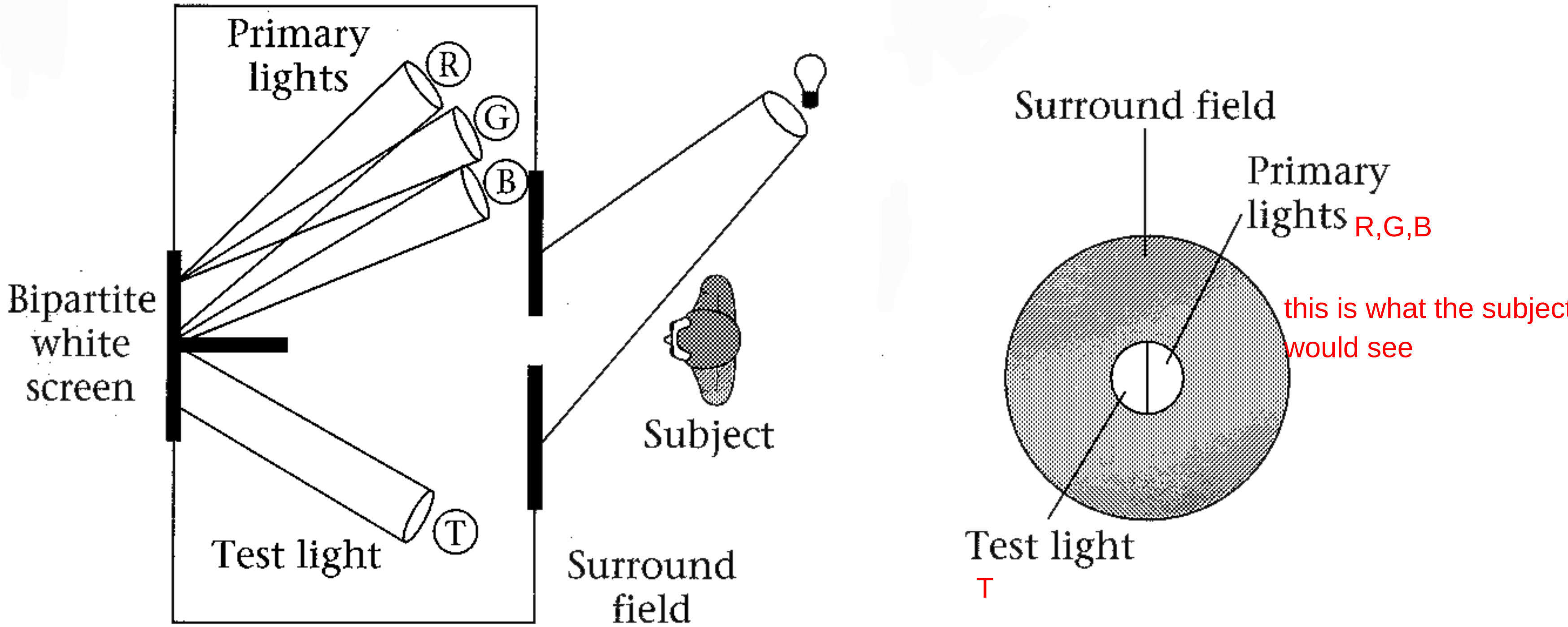


Fig. 21 shows an adaptive optics view of the mosaic of L (red), M (green) and S (blue) cones in four human subjects with normal color vision. The ratio of S to L and M cones is constant but thaf of L to M cones varies from 1:2.7 (M:L) to 16.5:1 (L:M). (adapted from Williams).

(or Stiles experments - stiles is the experimenter)

Color matching experiments

can be any primaries, but need to be independent. a primary should not be reproducible from another primary (need to be linearly independent so to say)



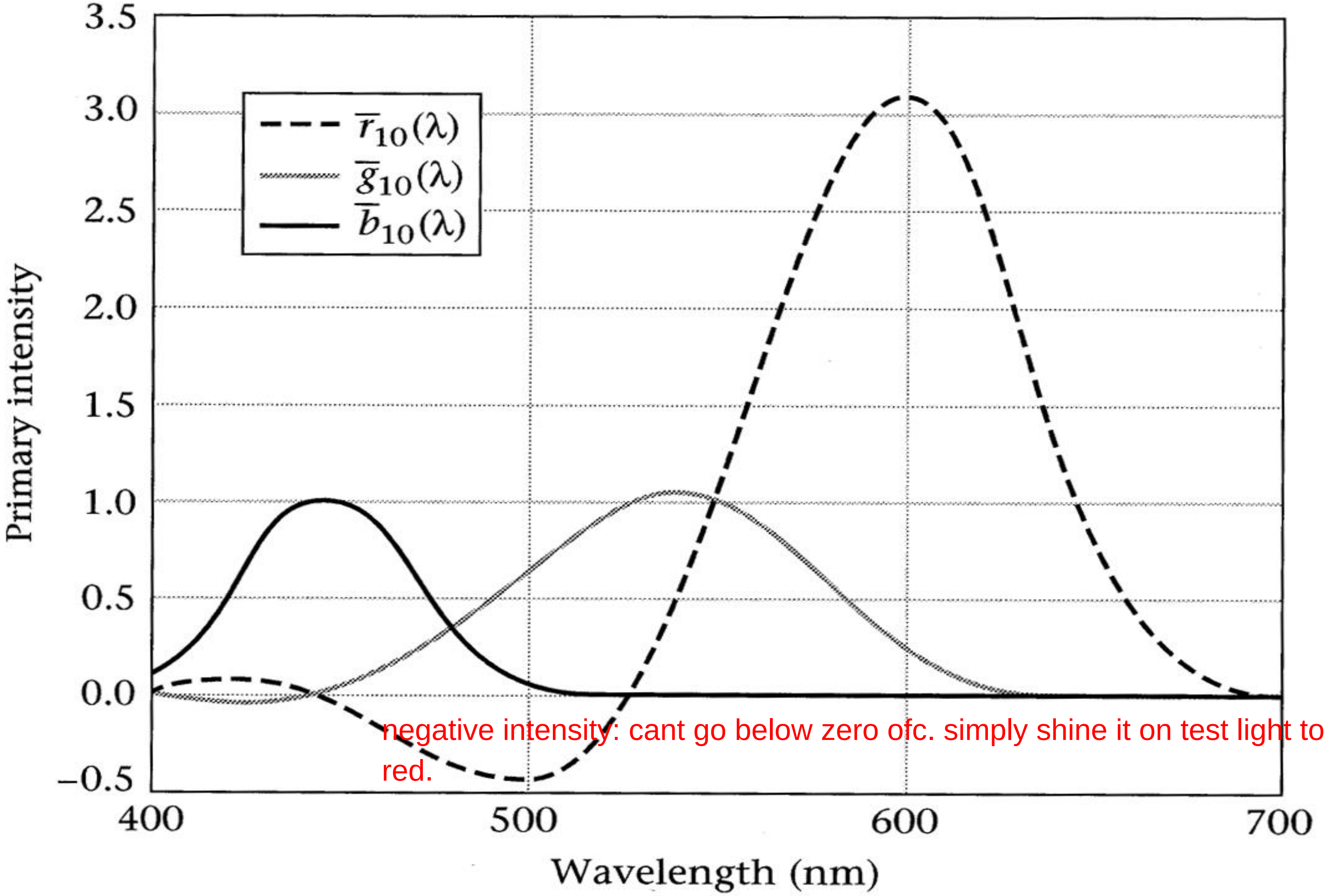
subjects had to adjust RGB such that its combination is like T test light

Wandell, 1998, plate 4.10

hamw many primaries do we have?

Color matching: results

these are the curves, stiles found out



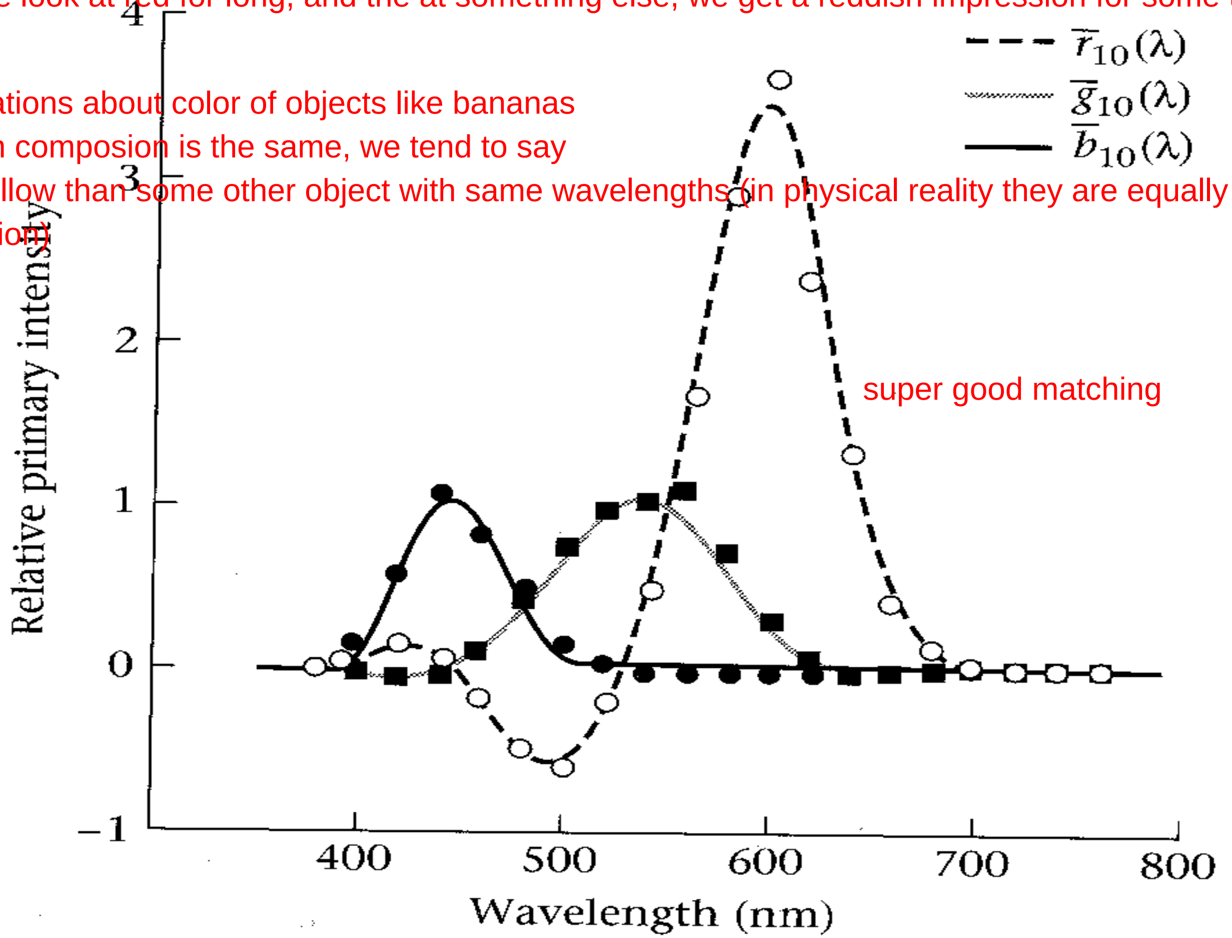
negative intensity: cant go below zero ofc. simply shine it on test light to simulate negative red.

Color matching: predictions vs. data

if we know the cones, you know what your subject perceives equivalently in terms of color

these data does not allow to predict how a color looks like, since what other wavelengths are around it, size of it etc.
also adaptation: if we look at red for long, and the at something else, we get a reddish impression for some time

we also have expectations about color of objects like bananas
so even if wavelength composion is the same, we tend to say
bananas are more yellow than some other object with same wavelengths (in physical reality they are equally "yellow" since same wavelength composition)



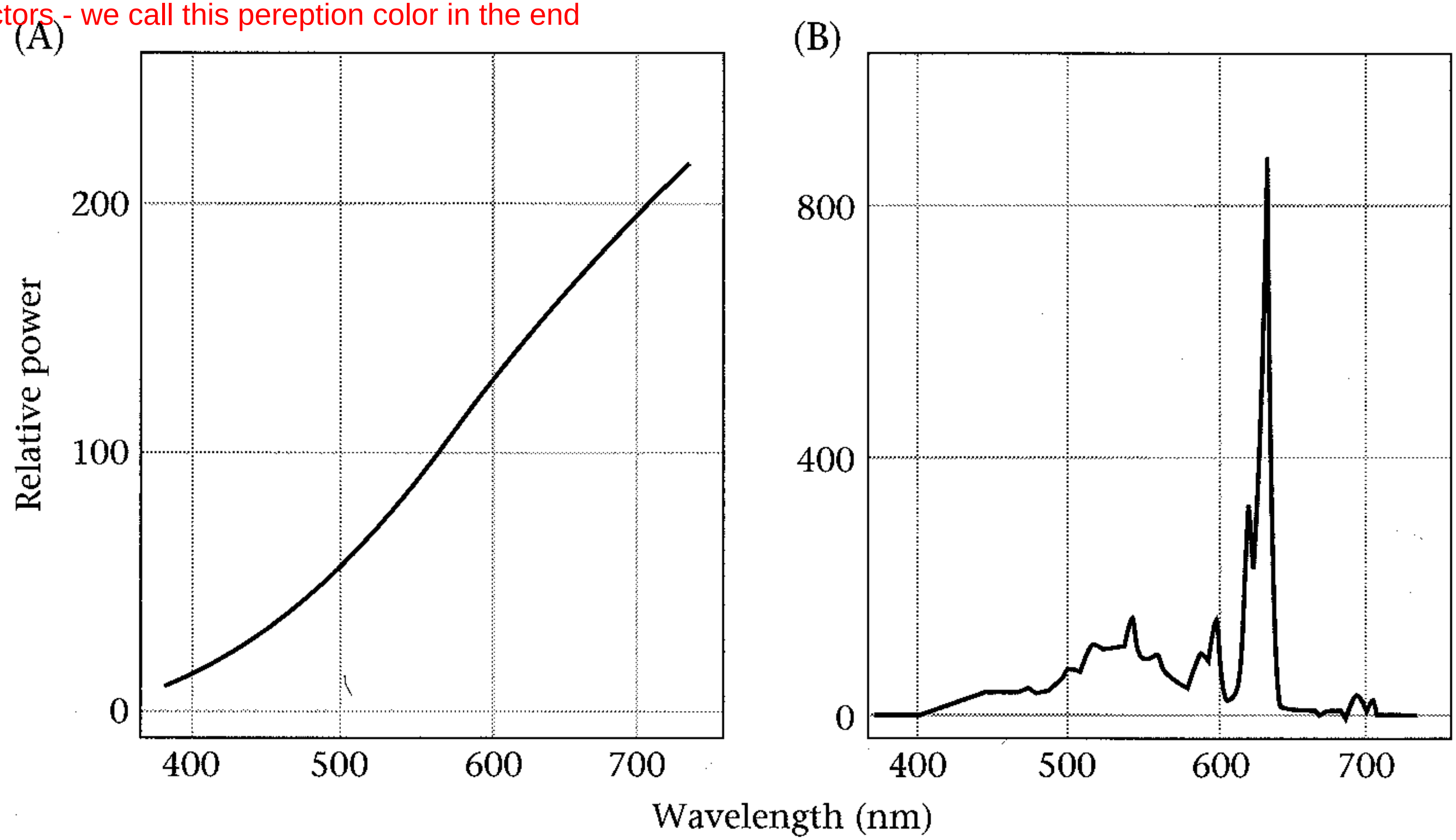
super good matching

hue: it's the color in trivial language.
saturation: how much white does the hue have - its combination is actually called color

psychophysics of color vision: huge body and keeps you busy for rest of life

Two metameric spectral distributions

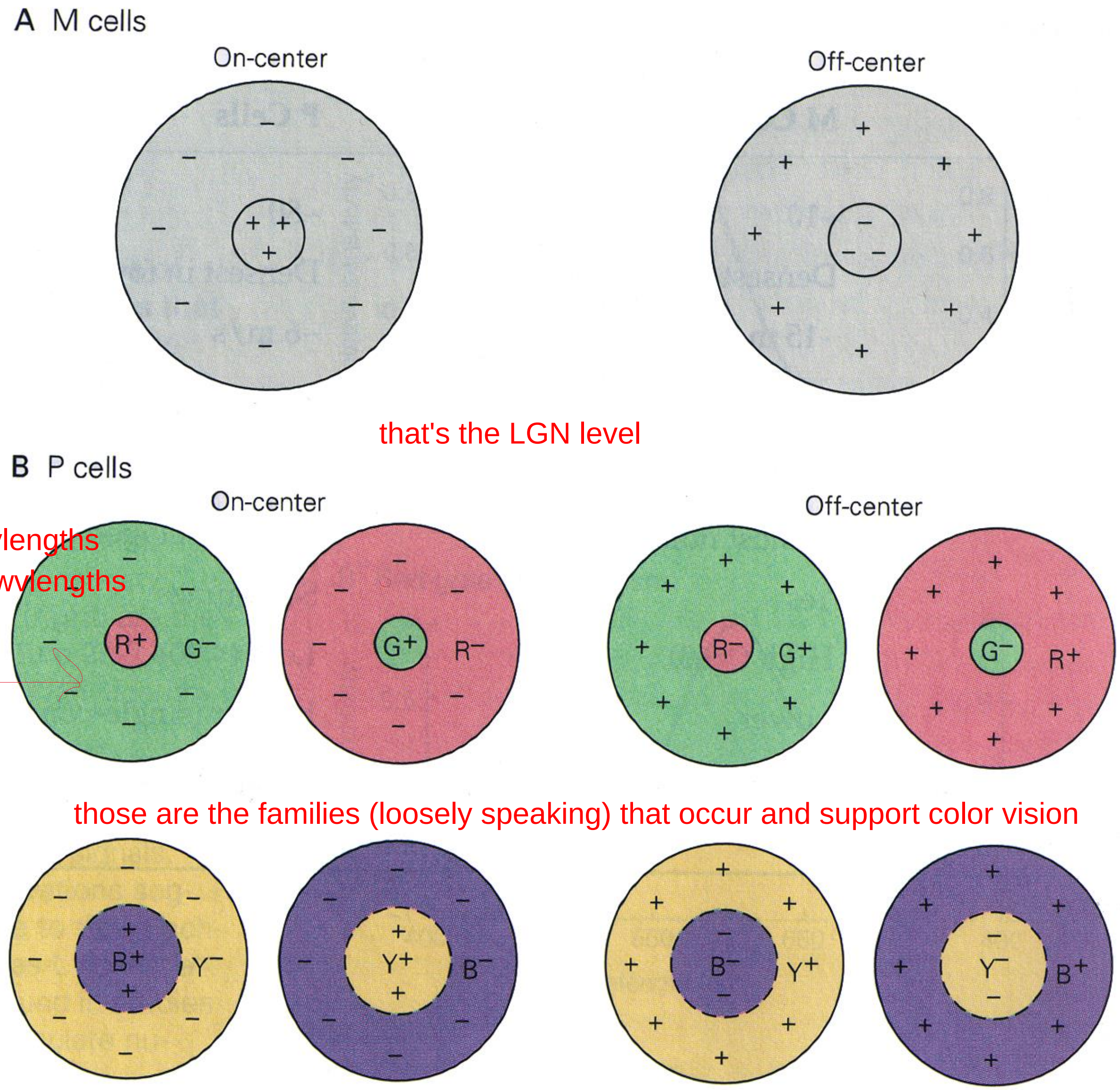
color is not a phyiscal property of an object - physically speaking it's wrong. it the human interpretation of wavelength interpretation and other factors - we call this pereption color in the end



Wandell, 1998, plate 4.11

LGN neurons - same as in the retina

Receptive fields of LGN neurones



that's the LGN level

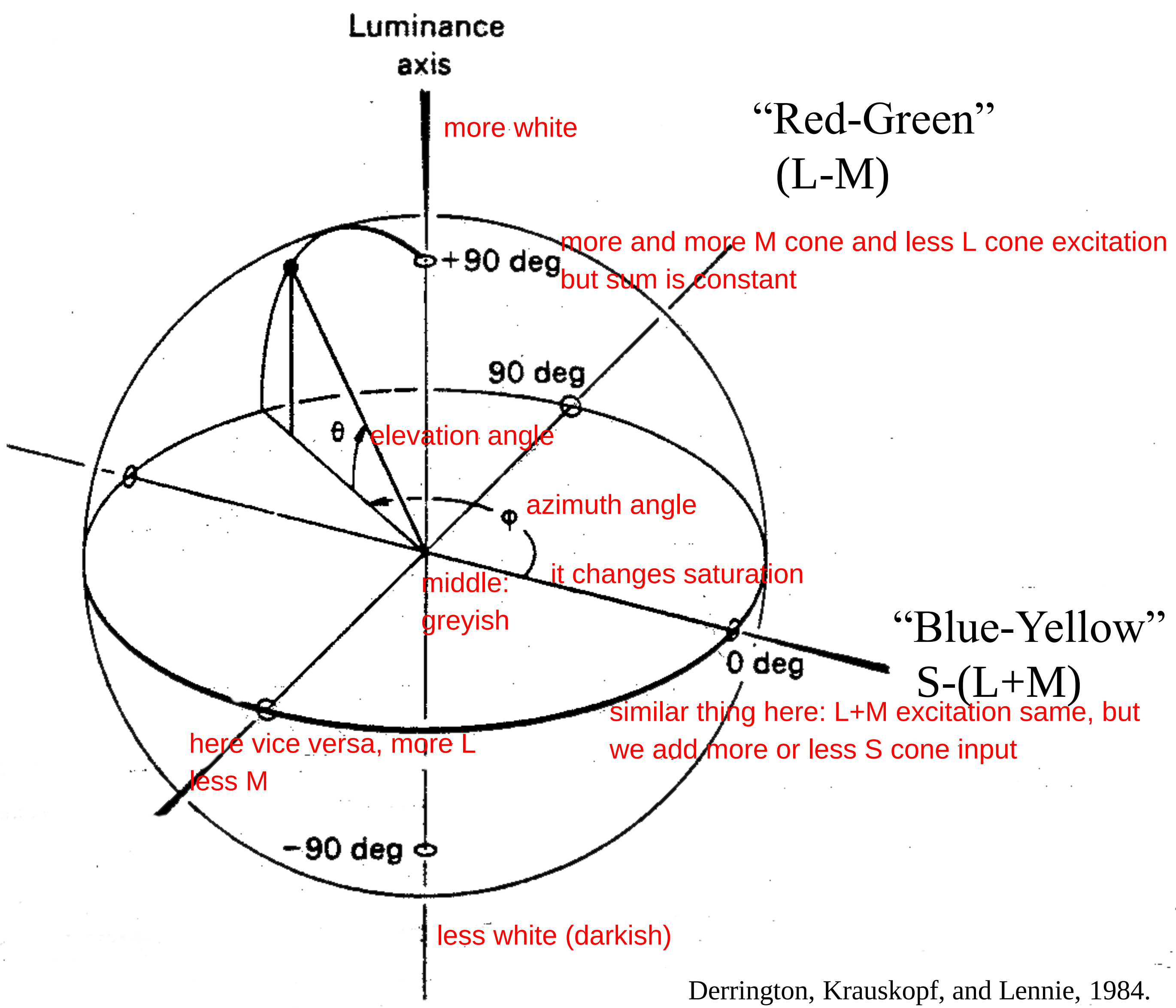
center only receives long wvlengths
surround only receives mid wvlengths

those are the families (loosely speaking) that occur and support color vision

The "DKL" color space

color space: based on excitation of cones in primates.

based on excitaation of cones



Derrington, Krauskopf, and Lennie, 1984.

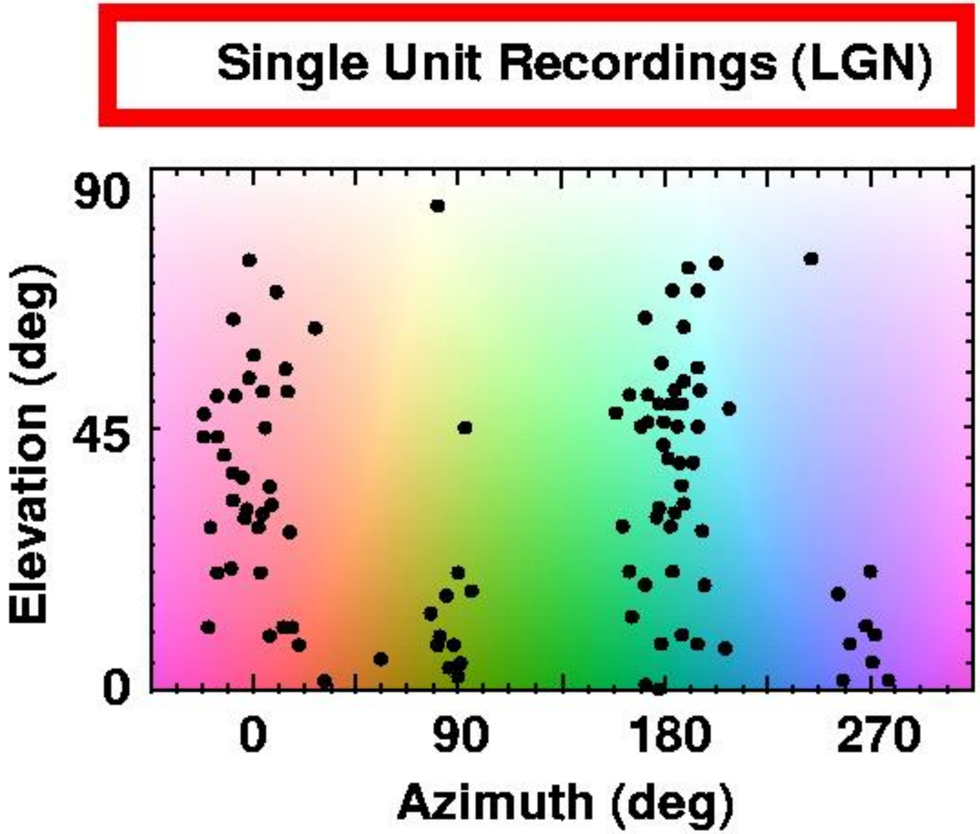
DKL

each point represents one cell.
each cell has a preferred colour for excitation which has a specific angle info from previous slide.
2 clusters: red/green (the high ones) abd blue yellow.

Preferred color of pLGN neurones

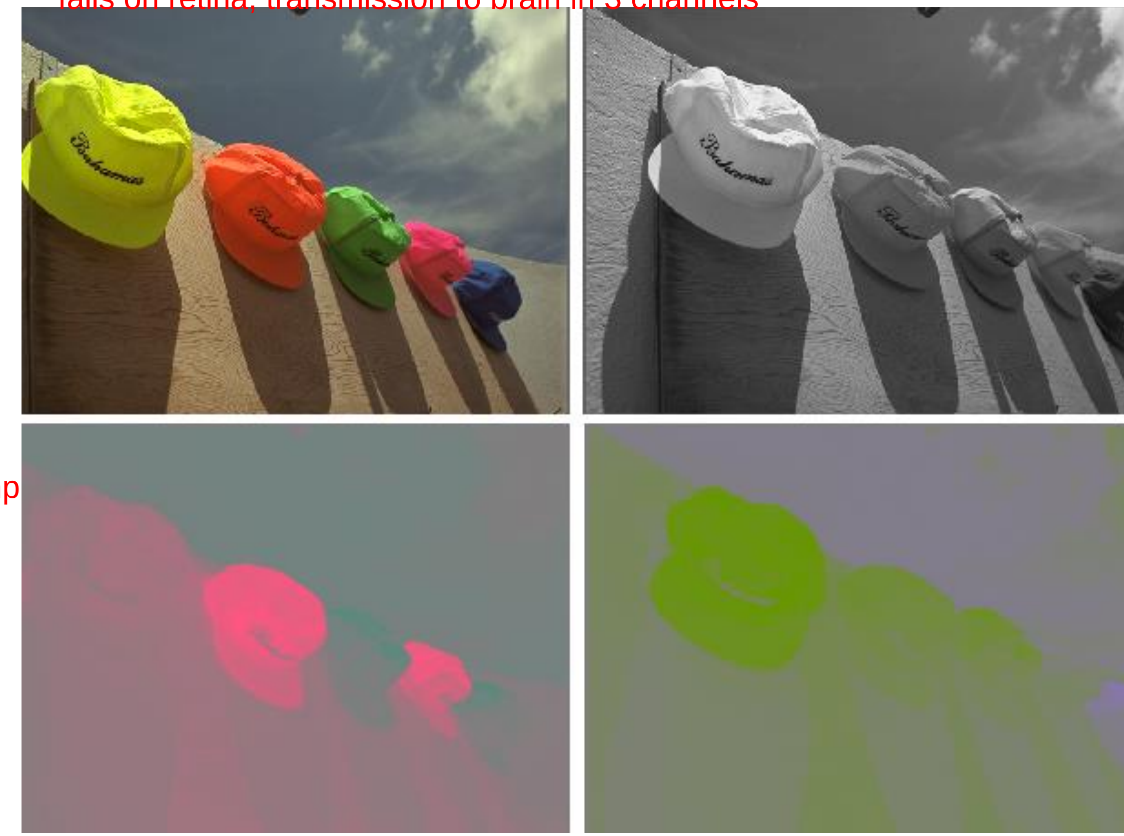
p for parvo

cells with a very high elevation are black/white cells (do not care about colour so much)



The world seen through the LGN

falls on retina, transmission to brain in 3 channels



channel 1: light intensity, black and white

channel 2: red green comp

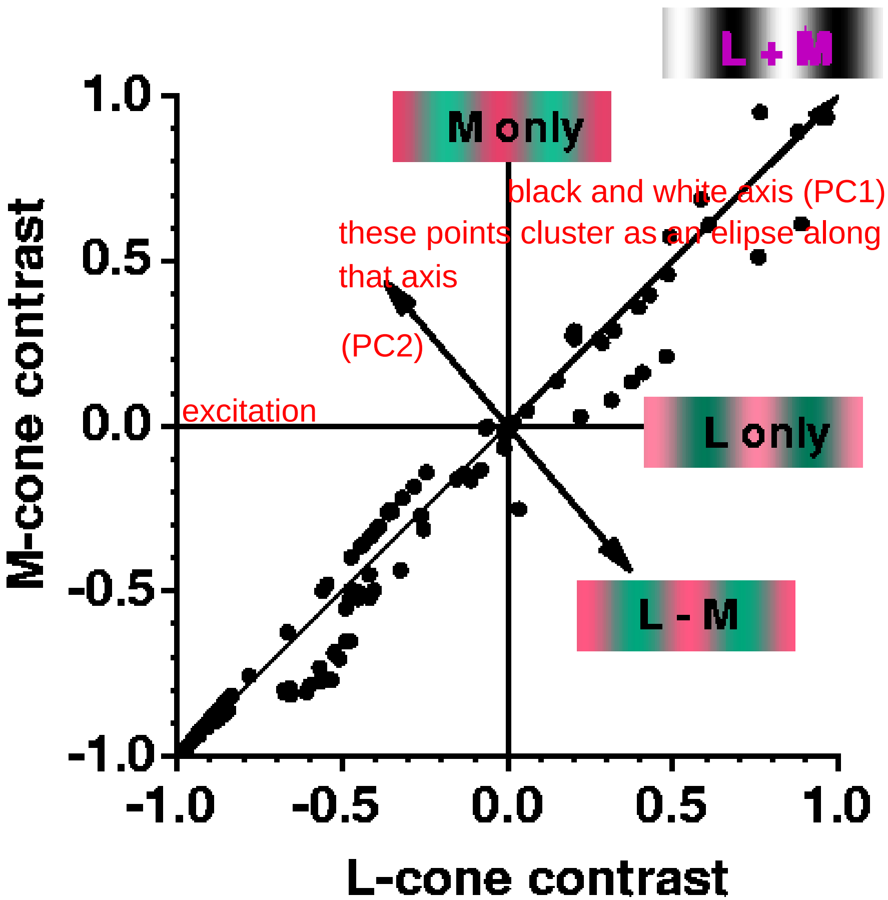
channel 3: blue yellow comp

why is it that in evolution, visiual system developed cells with red/green etc?

cluster of points like that are summarised in this manner so that most variation of information can be transmitted in a limited capacity channel (or something like that)

Color contrasts of natural objects

like forests, scenes etc.



black and white axis (PC1)

these points cluster as an elipse along that axis

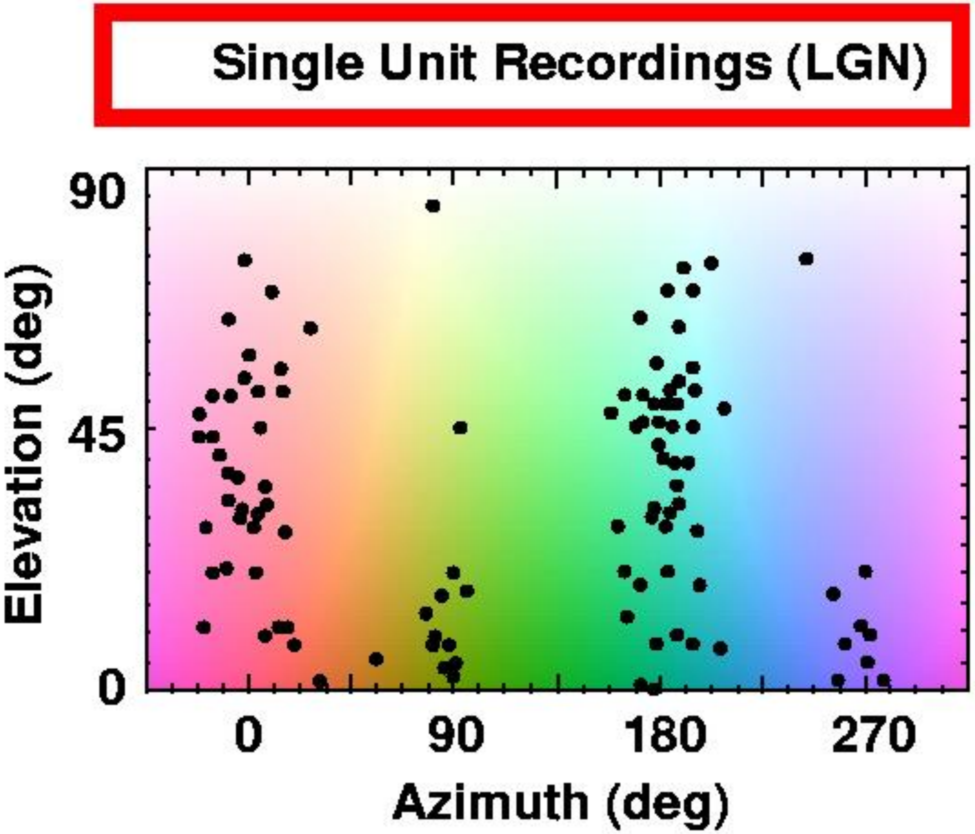
(PC2)

excitation

we sort of remove redundancy in the data

does not include blue/yellow axis, but it would be described just the same like this skipped literally

Preferred color of pLGN neurones



ignore these symbols

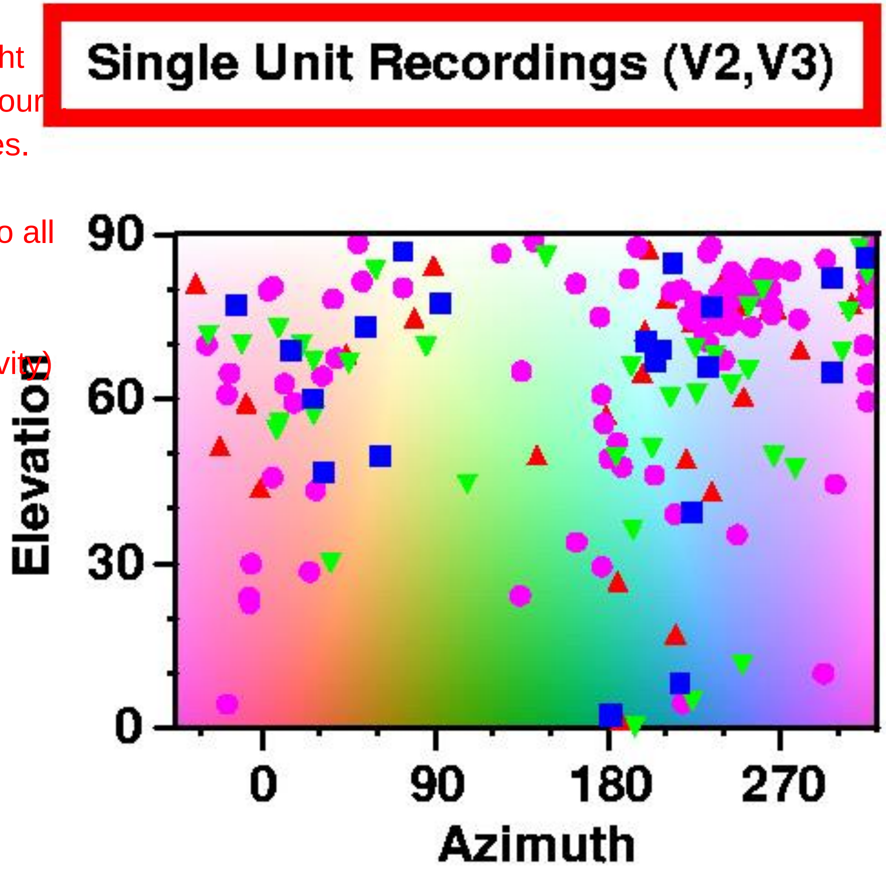
Preferred color of cortical cells

no clustering really, much more uniform distrubution of rpeferred colours. this means, the colours are not really primaries, but intermediate colours.

many of these cells are located high, they are interested in variations of light intensity. to some extent they like colour but they focus more on light intensities.

so, in the cortex, cells respond best to all sorts of colours.

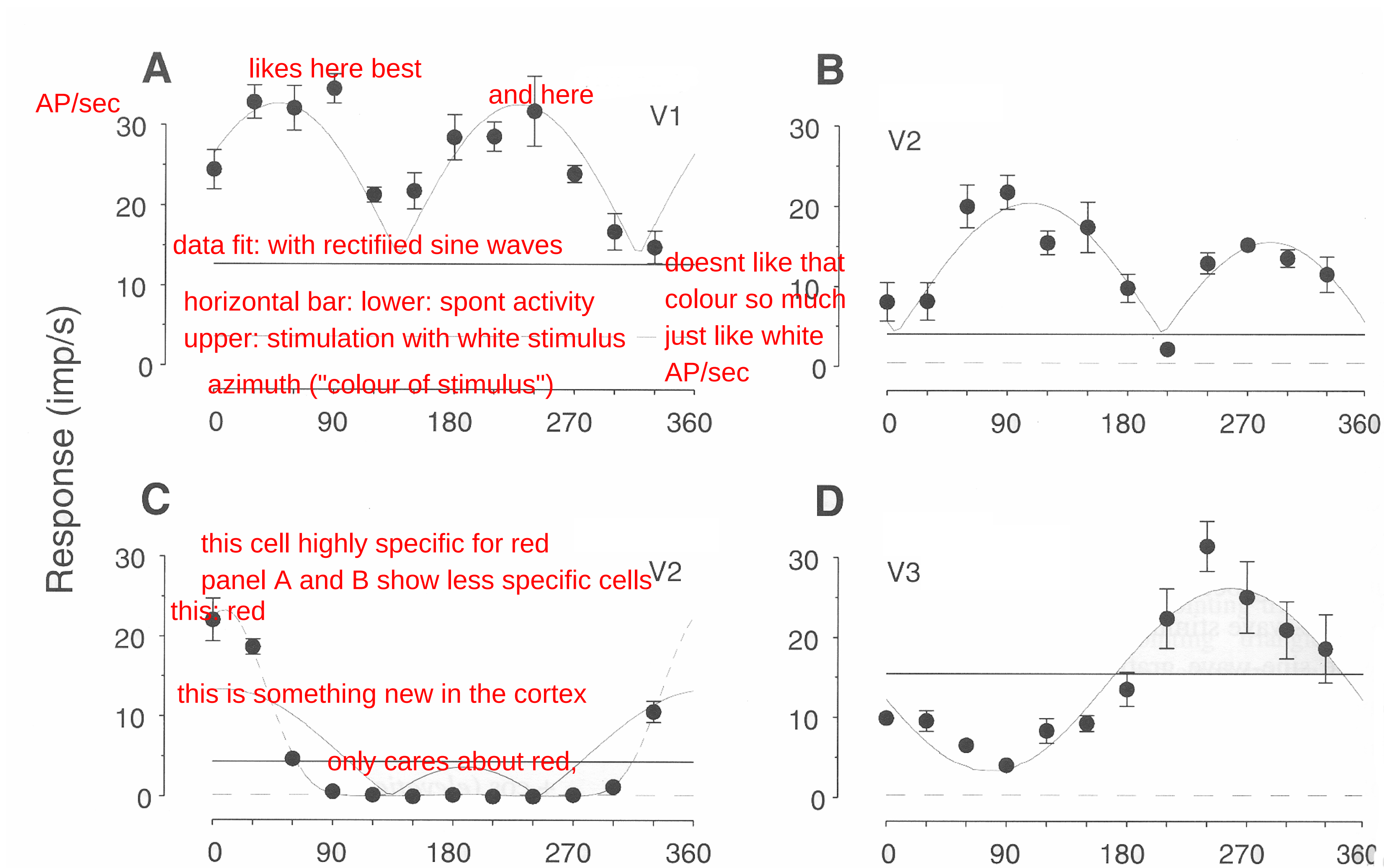
2nd difference see next slide (selectivity)



4 different cells recorded in V1-3

Examples of cortical cells' responses to color variations

preferred colours more widely distributed in cortex and more selective in cortex - that's the difference between retina/LGN and cortex



V3: cares more about motion and depth, not so much about colour, so many are not so specialized for colours

V2: there are very specialized cells for colours (panel C)

Three stages of color processing