Colour perception &
Colour names

Gunilla Borgefors, Vi2
gunilla@cb.uu.se

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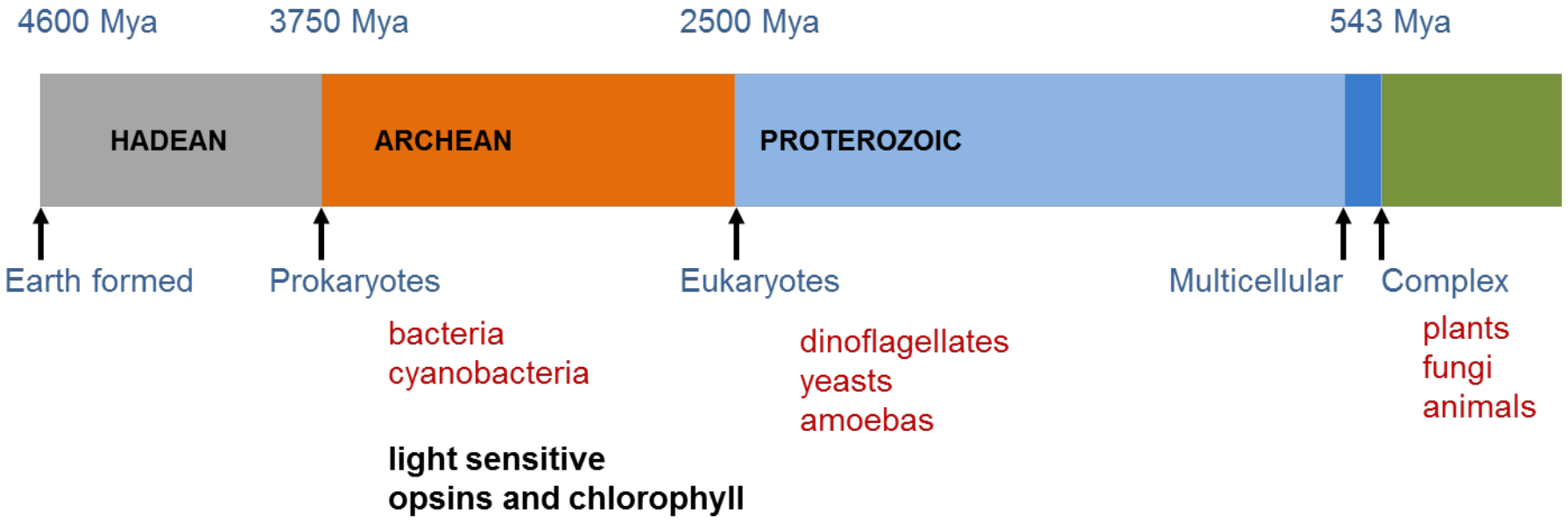
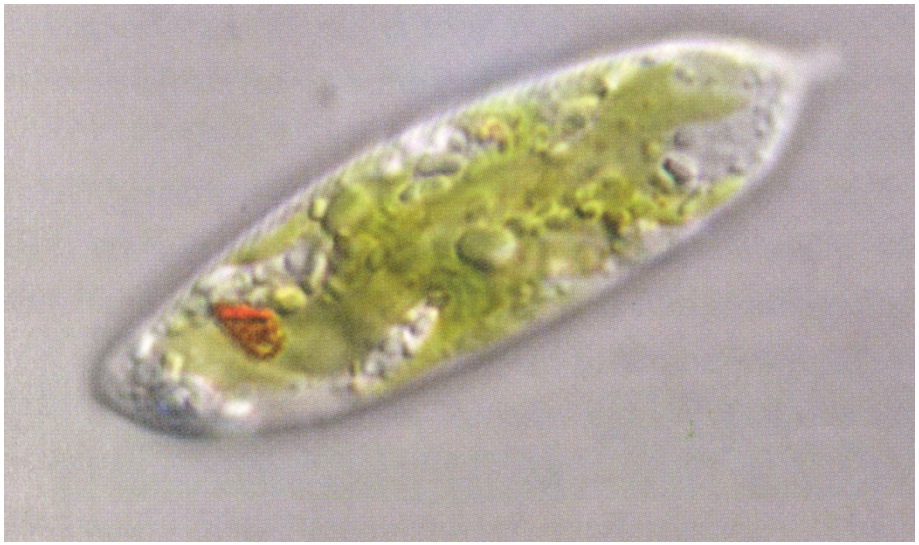
Life on Earth



Protist with eye-spot



E. gracilis is a flagellate, that *eats bacteria* **and** has *photosynthesis*. It remains from before the plant-fungus-animal split.

Eyespot is used to move towards light for better photosynthesis.

Eyes

In the Archean a procaryote created a protein sensitive to blue light called an opsin. This happened only once!

Eyes have developed independently at least 20 times, starting from a light-sensitive spot by:
bulg (most invertebrates)
pit (most vertebrates and octopi)

Computations show only 100 000 generations needed from eye-spot to camera eye!

Opsins

Opsins changed to be most sensitive to different light wave-lengths.

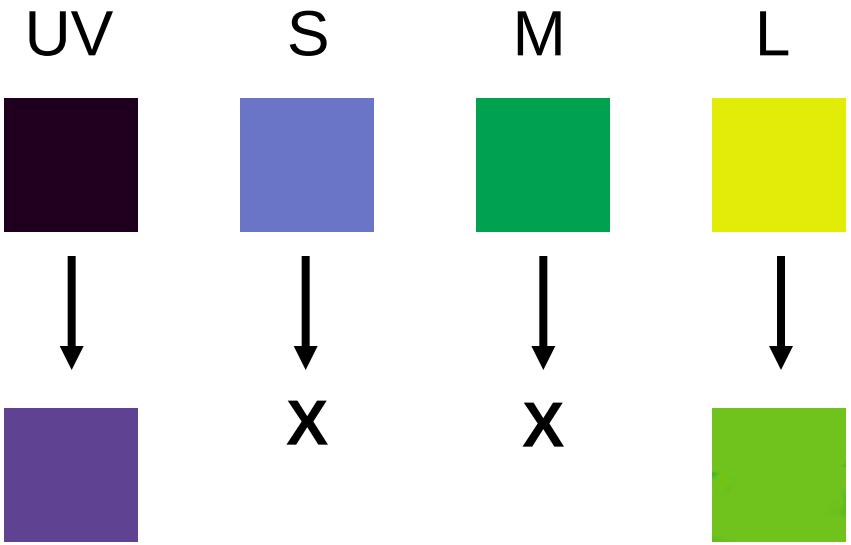
Red is hardest, as it has least energy

(dragonflies has the “reddest” opsin discovered).

Vertebrate opsins

Fish ~440 Mya

+ Rhodopsin for night vision

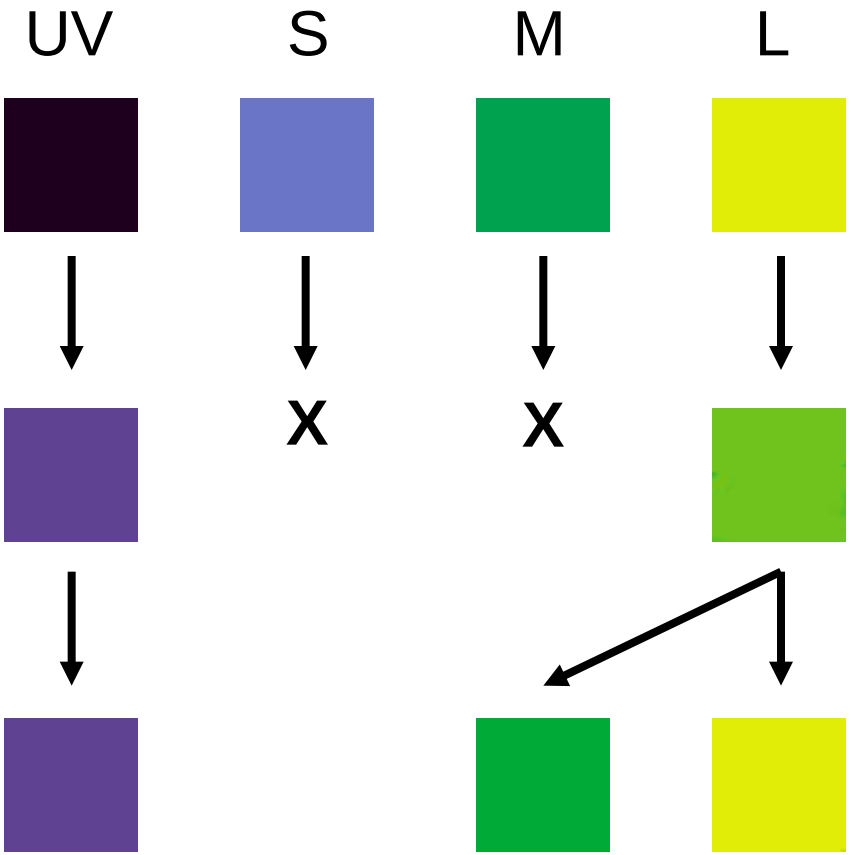


Vertebrate opsins

Mammal opsins

Night active, 160 Mya

+ Rhodopsin for night vision



Vertebrate opsins

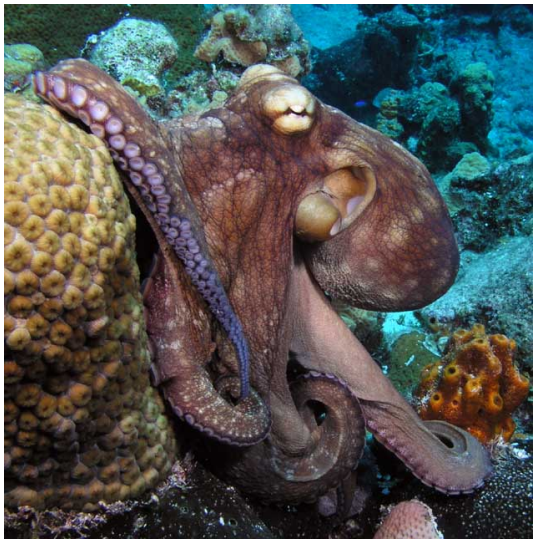
Mammal opsins

Simian opsins

35 Mya

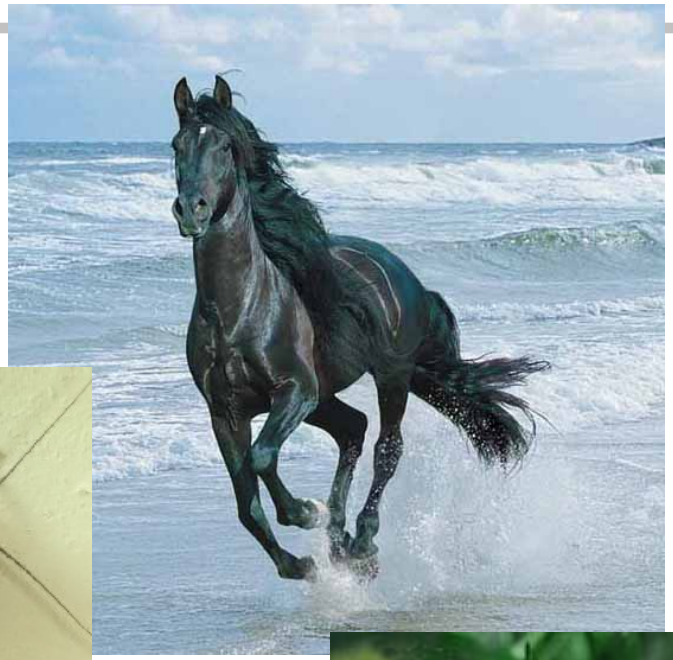
+ Rhodopsin for night vision

Monochromates



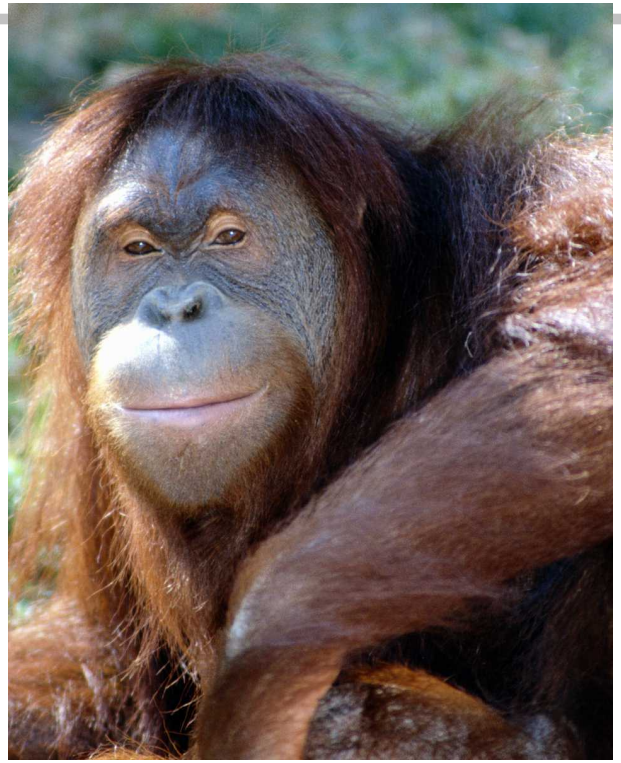
1

Dichromates



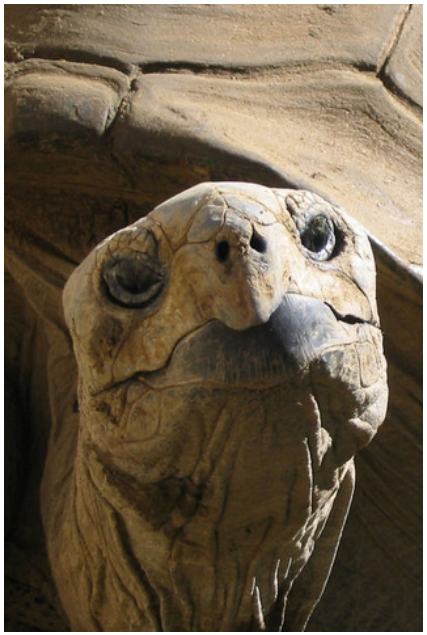
2

Trichromates



3

Tetrachromates



4

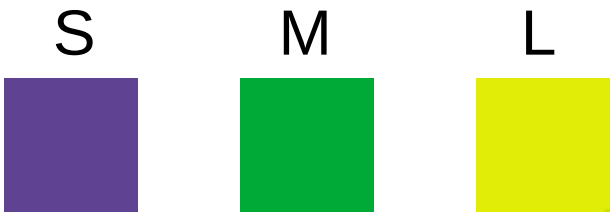
Pentachromates

5

Hexadecachromate

Mantis shrimp
A coral reef hunter that crack clams and stuns fish with the fastest punch in the world.

16

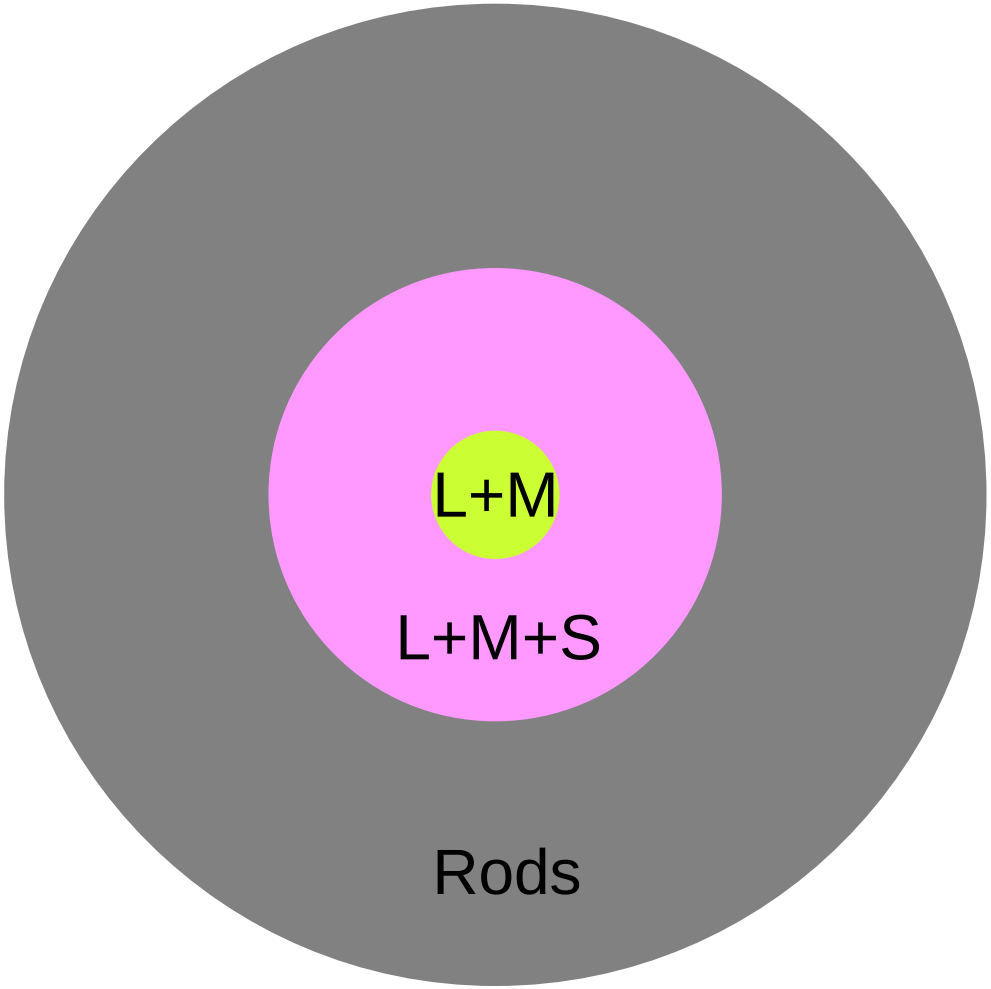


Human opsins

S, M, and L are found in the cones in he retina

Rhodopsine is found in the rods in he retina

Receptor pattern in retina



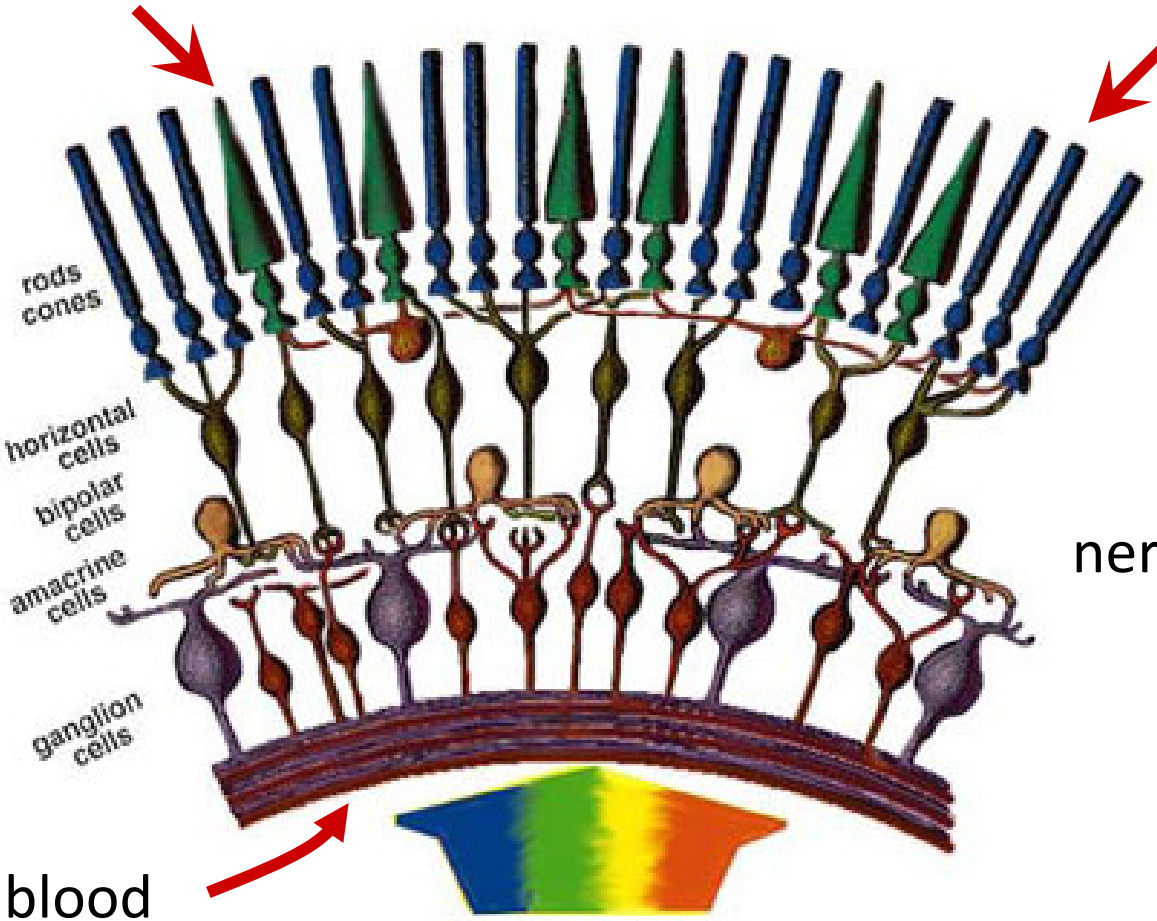
In fovea:
L : M = 2 : 1
very few S

Resolution in L and M is
10 times resolution in S

Human retina

4,5 x 10^6 cones

90 x 10^6 rods



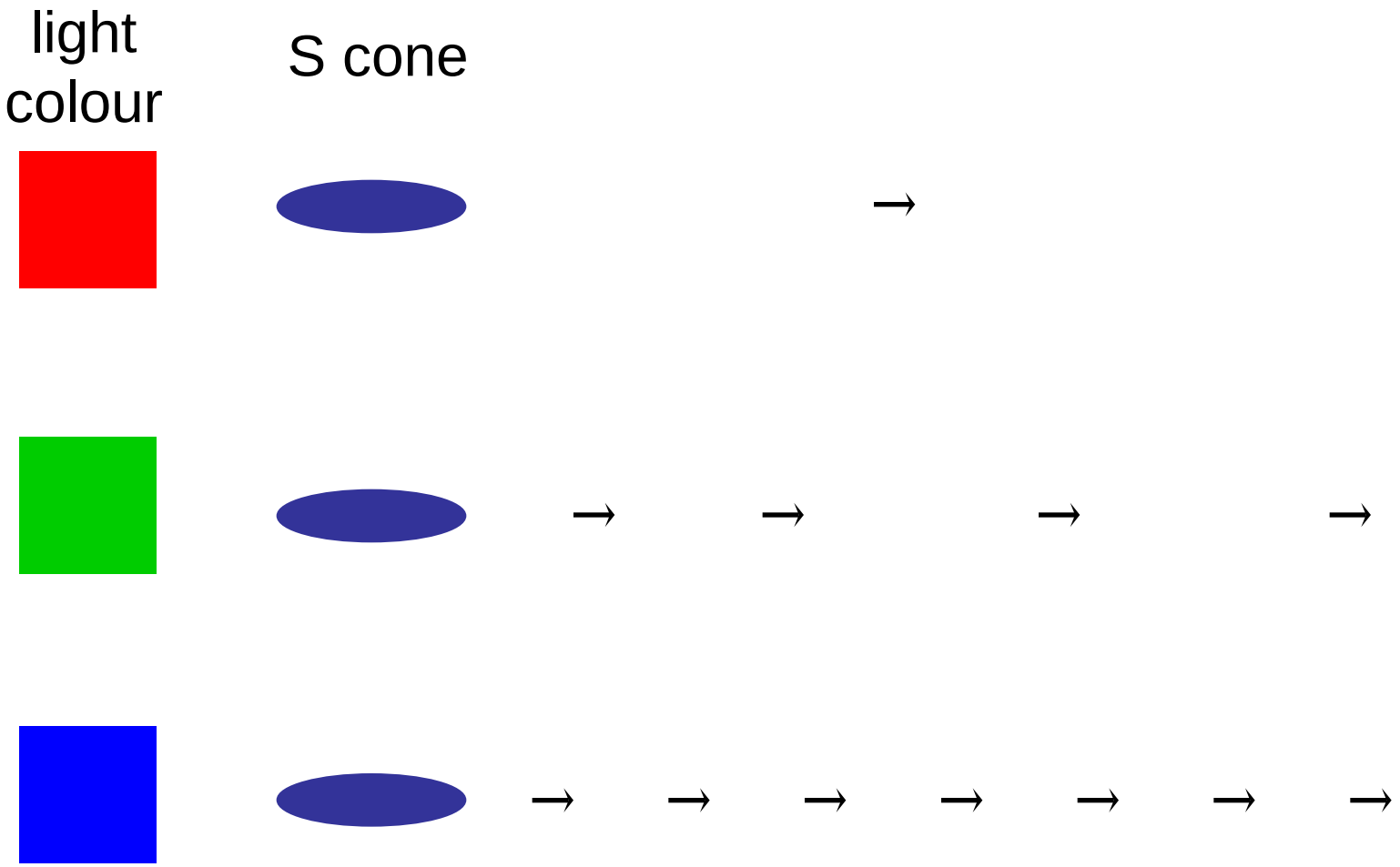
nerve cells

1,2 x 10^6 axons in optic nerve

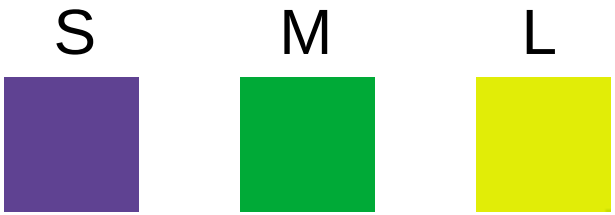
blood vessels

Light in

S cone signal



Optic nerve channels



Human opsins

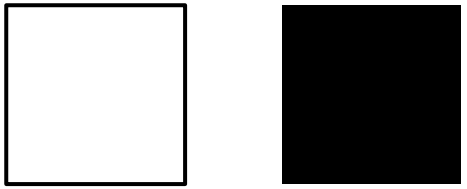
Lightness	M+L	
Hue1	M-L	”redness”
Hue2	S – (M+L)	”blueness”

Lightness for shape, distance, movement

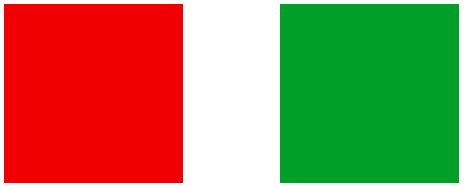
Colour for difference detection

Hering primaries (or “Urfarben”)

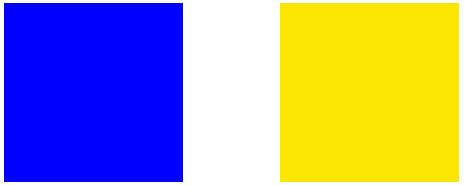
1892 Hering suggested the “opponent colour theory”...



M+L max and min



L-M max and min



S-(M+L) max and min

...even though he did not know about the three channels

Ewald Hering
1834-1918
German physiologist

Bird vision

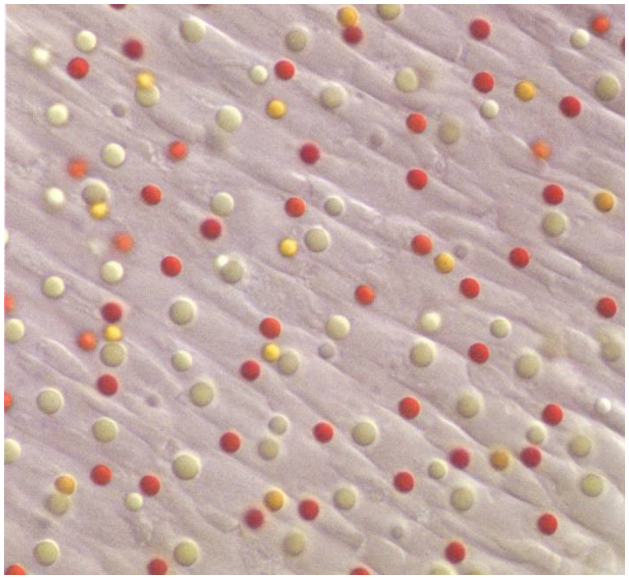
UV S M L

Bird opsins

Blue tit couple

The male has an UV-coloured head!

Laughing kookaburra

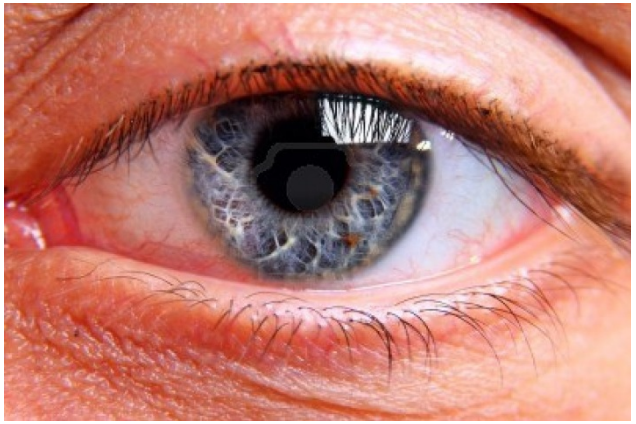


Four-colour vision is enhanced by five differently coloured oil droplets on the cones.

Red filters give better discrimination of greens.

Oils droplets are found in most types of eyes from earliest vertebrates onwards, but *not in mammals*. Different life-styles have different colour combinations. Kookaburras live in the forest.

Human eyes



The human eye is not the best – it is the brain that interprets signals that is unique.

For example: our retinas are thin and do less image processing than in other animals – so our vision is slower but more difficult to fool.

Colour discrimination

150 different hues 

200 different lightnesses 

150 saturations 

⇒

about **4.5** million colours

Concepts and Names

There are ***concepts*** (sexual organ of plant)
and ***names***
(flower, blomma, květina, цвет, fleur, gėlė, گل, kukka, 꽃, floro, 花)

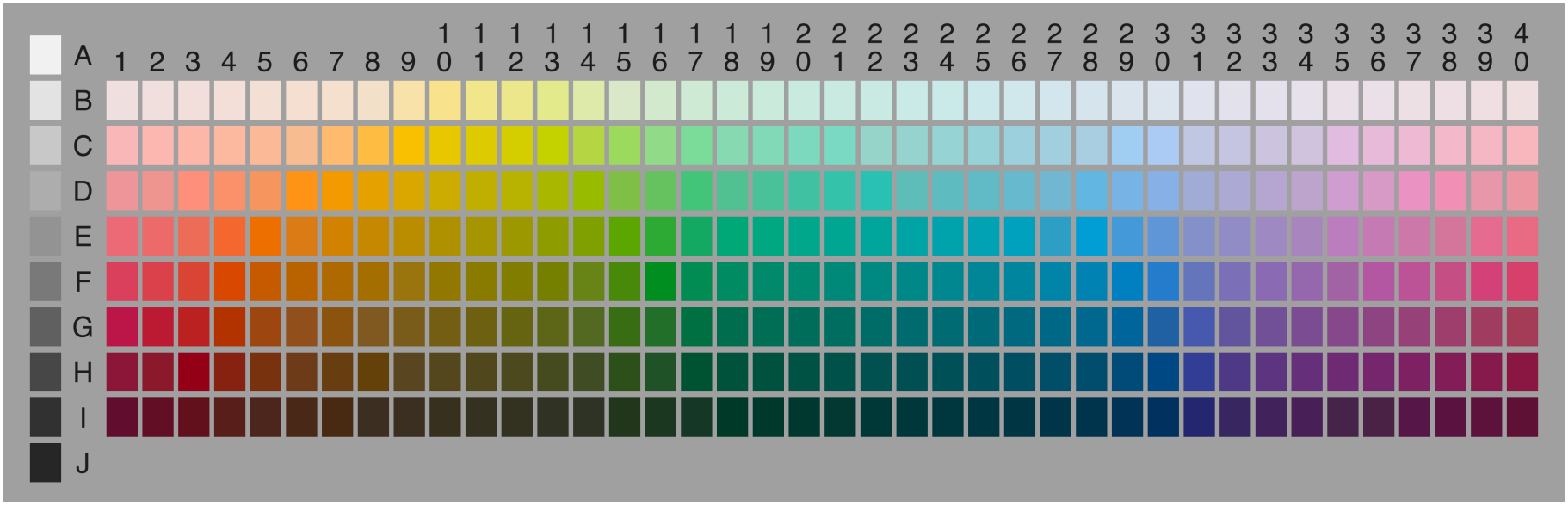
Nature school: concepts are universal, only names are different
- thus all humans think the same (Chomsky, Pinker, ...)

Culture school: both concepts and names differ
- thus humans' thinking is influenced by their mother tongue (Sapir, Whorf*, ...)

Colour is used as a ***model***, where concept = focus and range

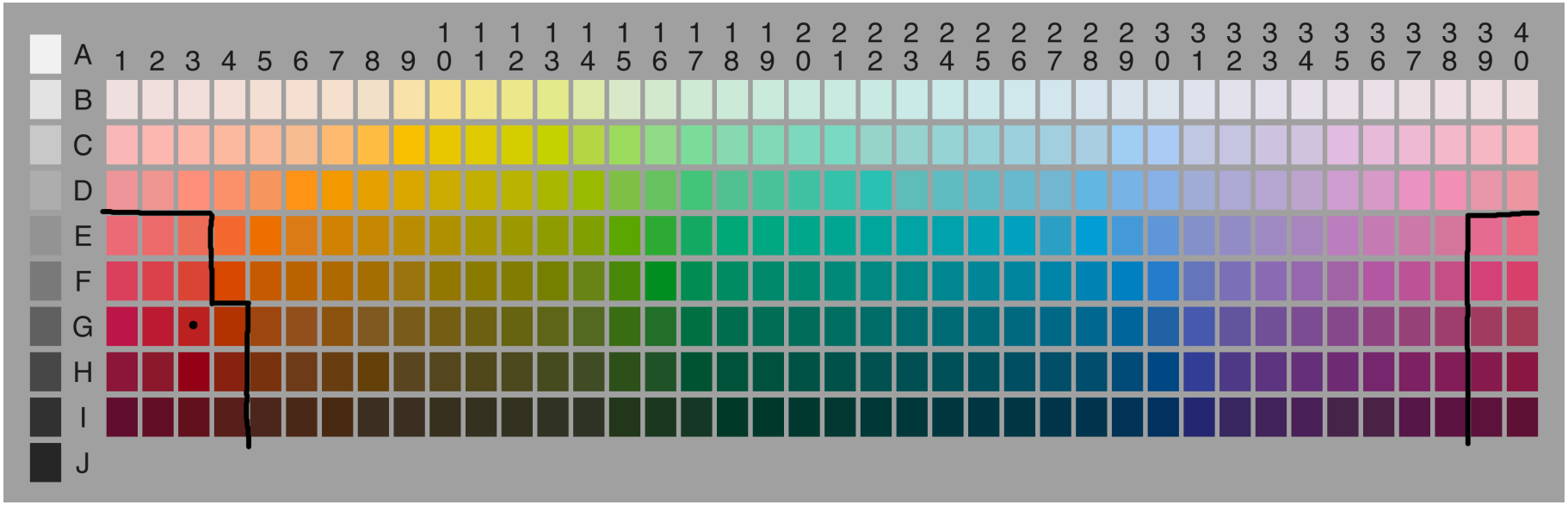
* Not Worf!

Munsell colour chips



From: Munsell 1915: *"Atlas of the Munsell Color System"*
Wadsworth–Howland Press, USA

Munsell colour chips



Focus – my most typical chip for “red”

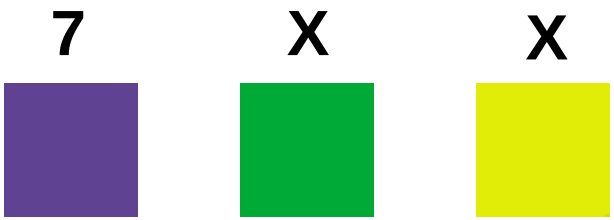
Range – all chips that I would call “red”

Mid 1800s

A number of people noticed the lack or strangeness of colour names in

- *Indian Vedic Poems in **Sanskrit***
- *Homer in **Greek***
- *Old testament in **Hebrew***
- *Quran in **Arabic***
- *Sagas in **Icelandic***

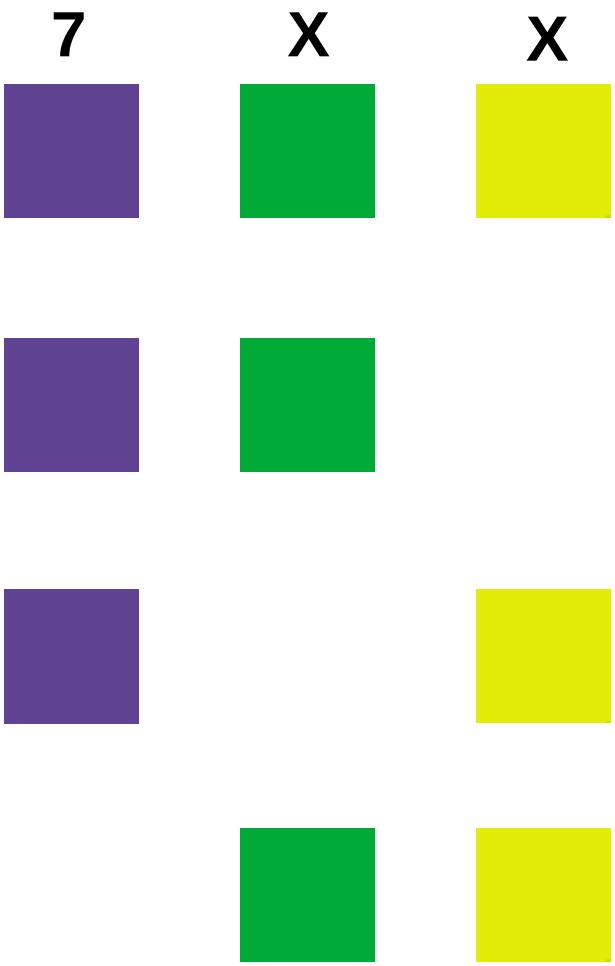
Conclusion: colour vision was recently evolved (Darwin!) so ancient (and “primitive” people) where colour blind.



Chromosome with opsin gene

Normal colour vision

Chromosome with opsin gene



Normal colour vision

Prontanopia
(red-green)

Deuteranopia
(red-green)

Tritanopia (rare!)
(blue-yellow)

M and L are less stable than S because they are evolutionary much younger

Colour “blindness”

Normal colour vision

Colour “blindness”

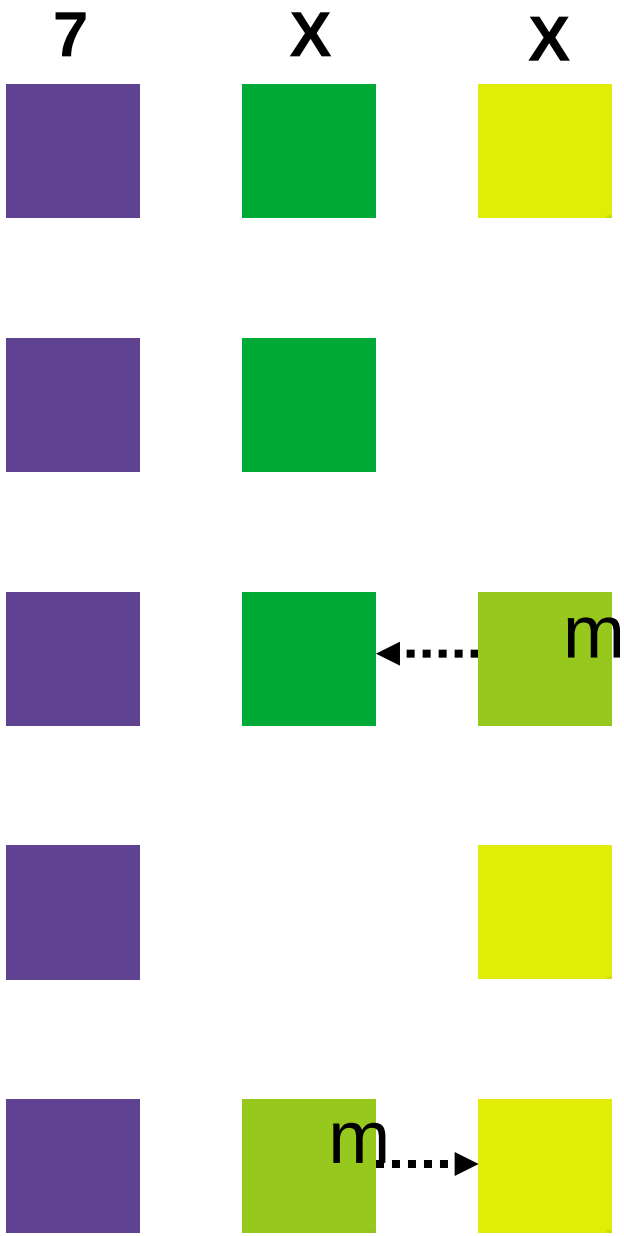
Prontanopia (red-green) *(most mammals)*

Colour “blindness”

Deuteranopia (red-green)

Colour “blindness”

Tritanopia blue-yellow



Chromosome with opsin gene

Normal colour vision

Prontanopia

Protanomaly

Deuteranopia

Deuteranomaly – *most common*

Colour “blindness”

Red-green blindness in about 8% men and 7‰ women.

Blue-yellow blindness in about 1‰ both men and women.

1875: Lagerlunda train crash

Two trains collided just outside my hometown Linköping.

Why? (In several meanings...)

1875: Lagerlunda train crash

Holmgren concluded the driver drove against a red signal because he was red-green colour-blind!

He devised an easy-to-handle test set.

Fritiof Holmgren
1831-1897
Prof. UU

Holmgren test wools

In a very short time, **all** railway and marine men all over the world were tested for colour blindness...

1870s-90s: Studies of “primitive” tribes

Physiologists (e.g. studying Nubians at Berlin’s zoo!)

Linguists studying native North American languages

Anthropologists going here and there

Missionaries going everywhere

Many had few colour names but *all* had equal colour vision!

Interest lost!

Conclusion:
The division of the colour spectrum is completely arbitrary!

and ***any*** ranking of languages and cultures became taboo

...but remember the Hering primaries

1969: New interest

Berlin & Kay 1969:

"Basic color terms: Their Universality and Evolution"

Brent Berlin
1936--
American anthropologist

Paul Kay
1934--
American linguist

Both at U California

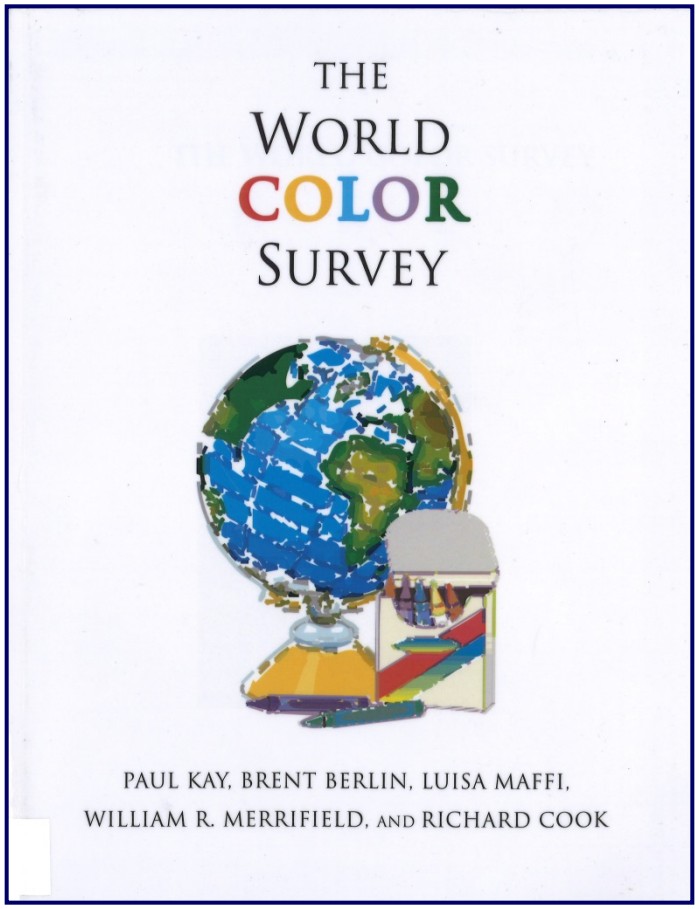
Based on many, mostly American, tribal languages

2009: World Colour Survey

Investigates 110 languages from all over the world, mostly collected in the **1970s.**

Native speakers were asked to name all the Munsell colour chips and results merged for several speakers.

The inventory has continued with many more languages.

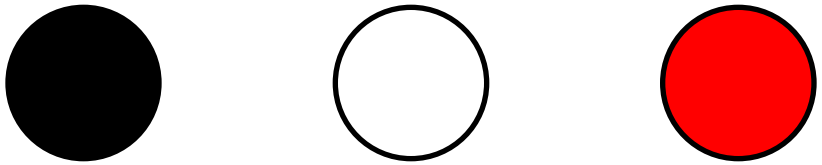


Basic Colour Terms

- Meaning is not understood from parts (yellow, not lemon)
- Cannot be contained in a larger category (yellow, not aureolin)
- Can be used for everything (yellow, not blonde)
- Adapts to the grammar (yellow-er, not amber-er)
- Consensus among native speakers
- High frequency in speech and writing
- Not a recent loan word
- Short response time for naming
- ...

All known languages have 2-12 BCTs

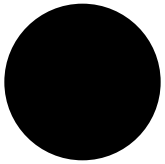
Chukchi BCT foci



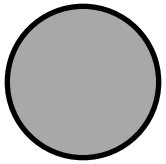
nukin **nidlikin** **tschetlju**

...as collected by Dr. Almquist from Skogstibble when the Vega expedition was frozen in the ice above Siberia 1878-89.

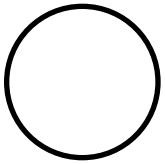
Swedish BCT foci



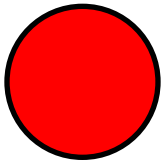
svart



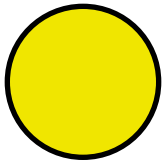
grå



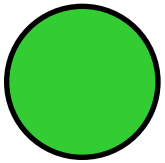
vit



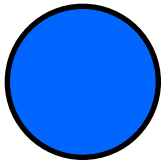
röd



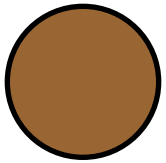
gul



grön



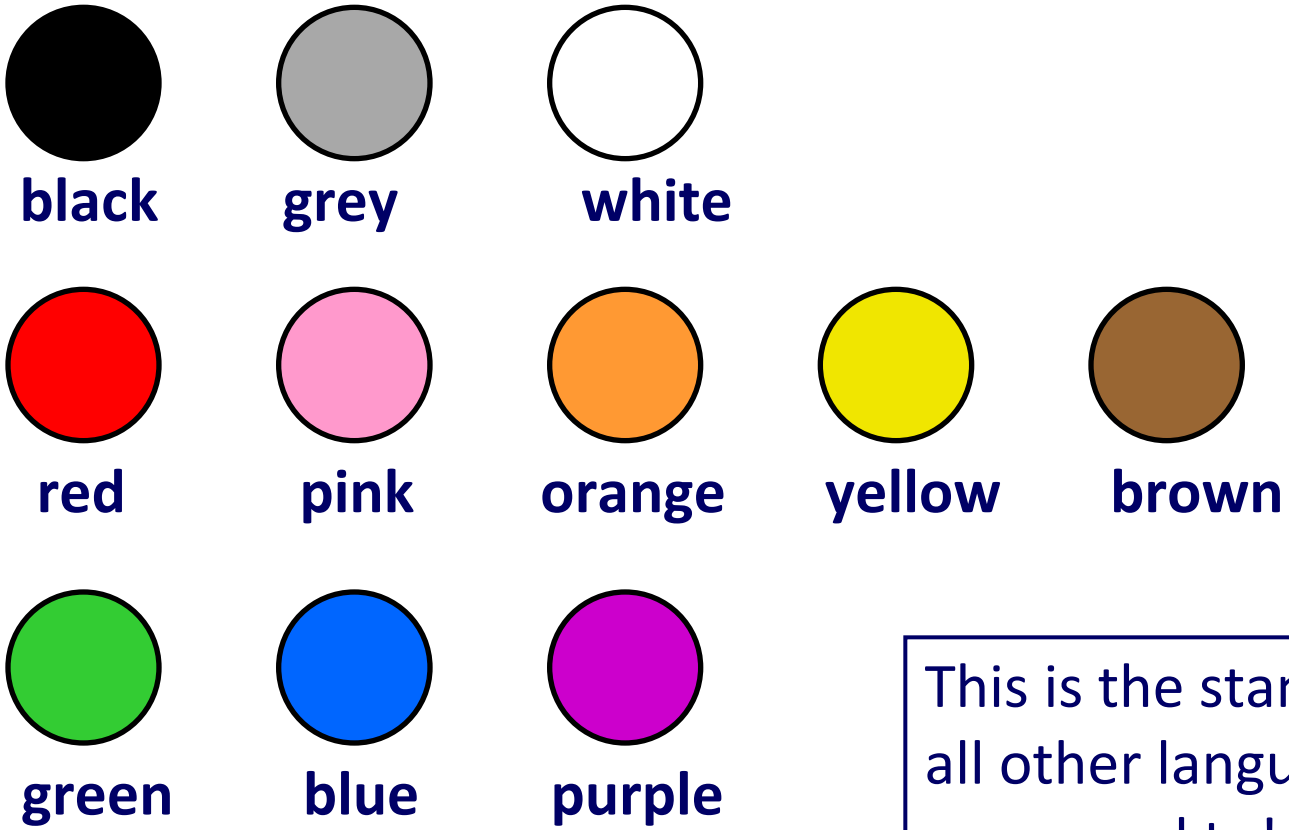
blå



brun

(according to me and investigations into place and plant names)

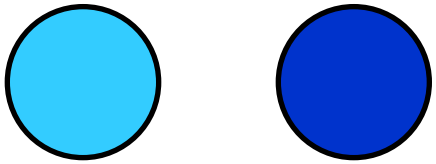
English BCT foci



This is the standard that all other languages are compared to!

More BCT foci

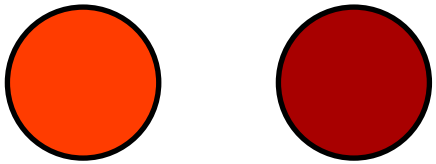
Russian has two “blue” BCT



голубой **goluboy**

синий **siniy**

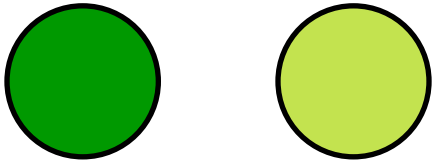
Hungarian has two “red” BCT



piros

vörös

Himba (Namibia) has two “green” BCT



2 BCT

black(+green+blue) and **white(+red+yellow)**

Ex. **Dani** (New Guinea)

mili (black, dark, and cold colours),
focus *dark blue* or *dark green*

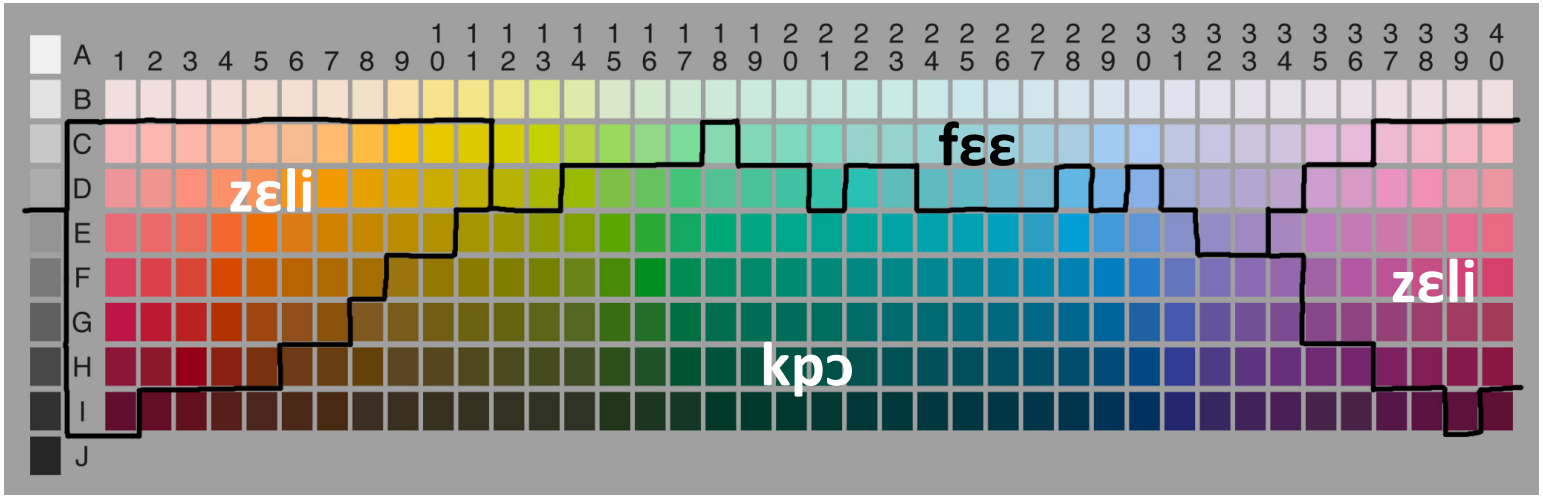
mola (white, bright, and warm colours),
focus *dark red* or *pink*

Language similarities

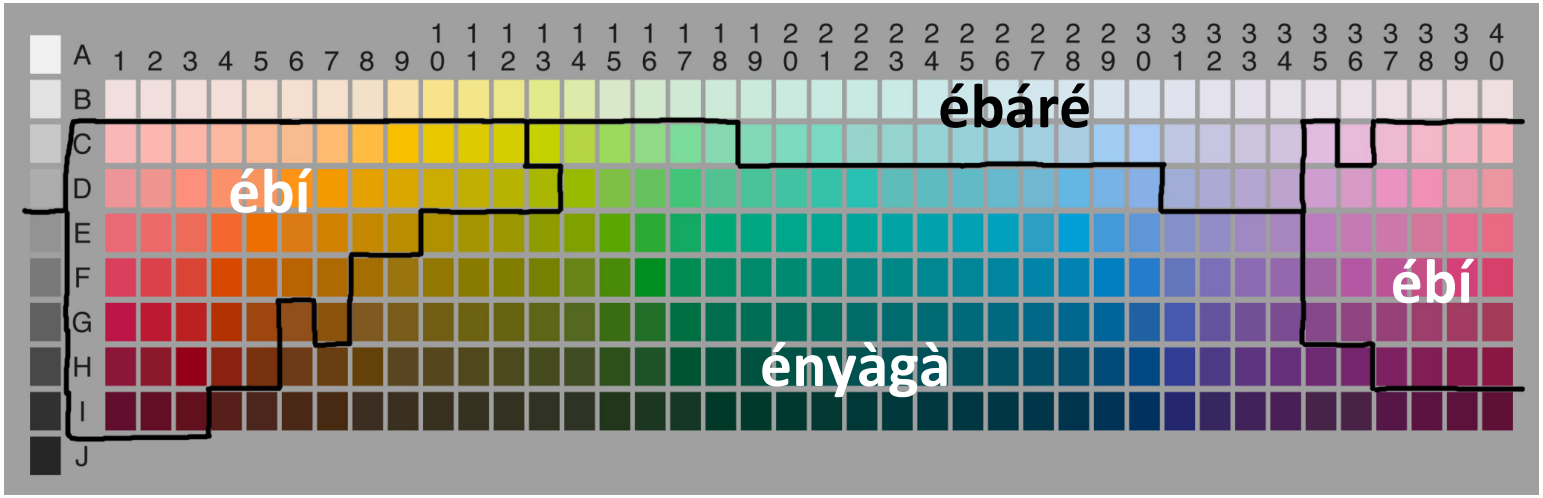
Languages with 2-6 BCTs do **not** have random foci and ranges!

ALL
2-BCT: dark/cold + light/warm
3-BCT: dark/cold + light + red – like Chukchi!

Language similarities – 3 BCTs



Bété
(Ivory Coast)



Ejagham
(Nigeria, Cameroon)

Language similarities

2-BCT: dark/cold + light/warm

3-BCT: dark/cold + light + red

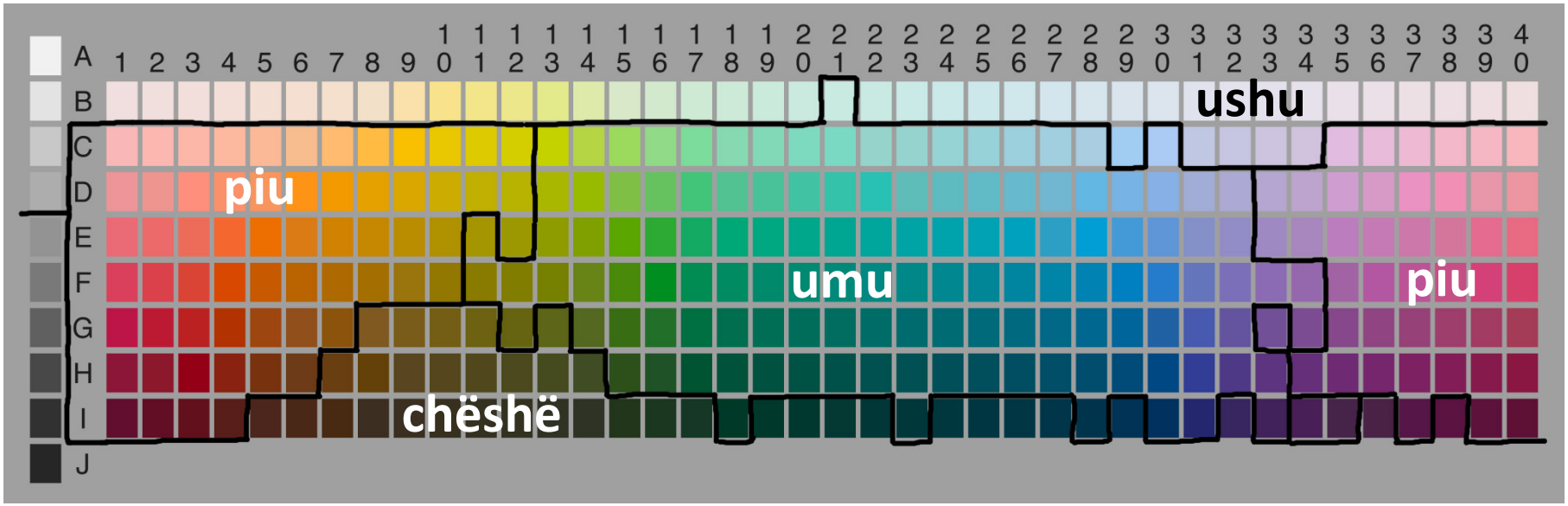
4-BCT: three possibilities (adding grue*, yellow, or non-red)

5-BCT: three possibilities

6-BCT: the Hering primaries!

*grue = **gr**een + **bl**ue

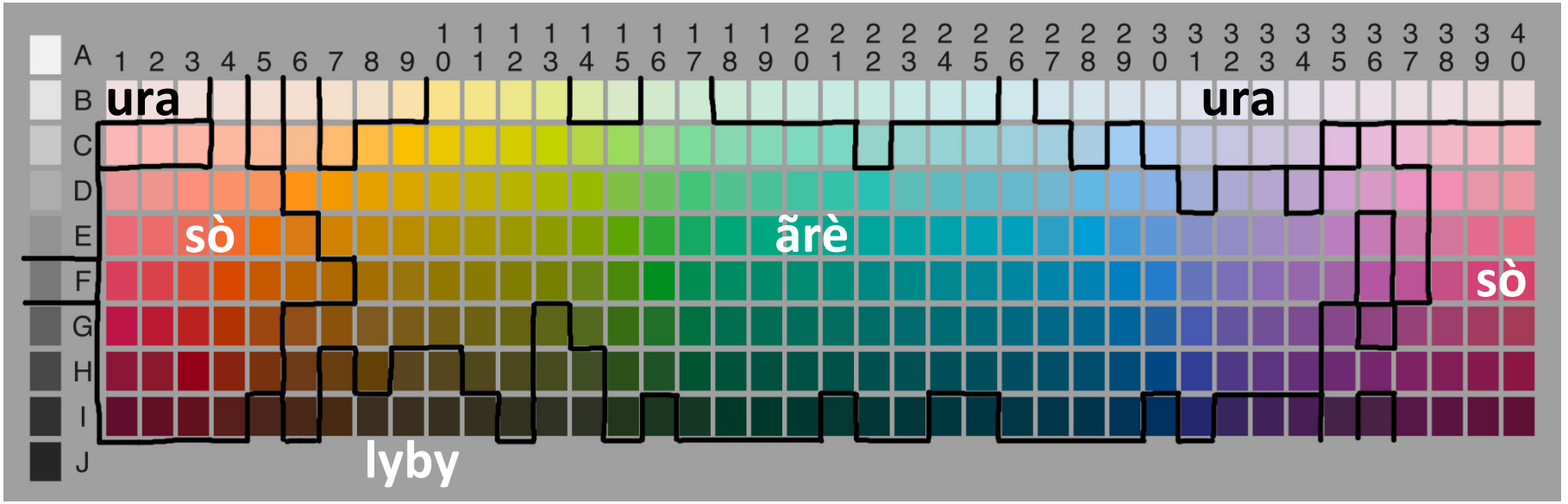
4 BCT - example



Mayoruna (Peru)

This is the most common 4 BCT pattern: light, dark, warm, cold

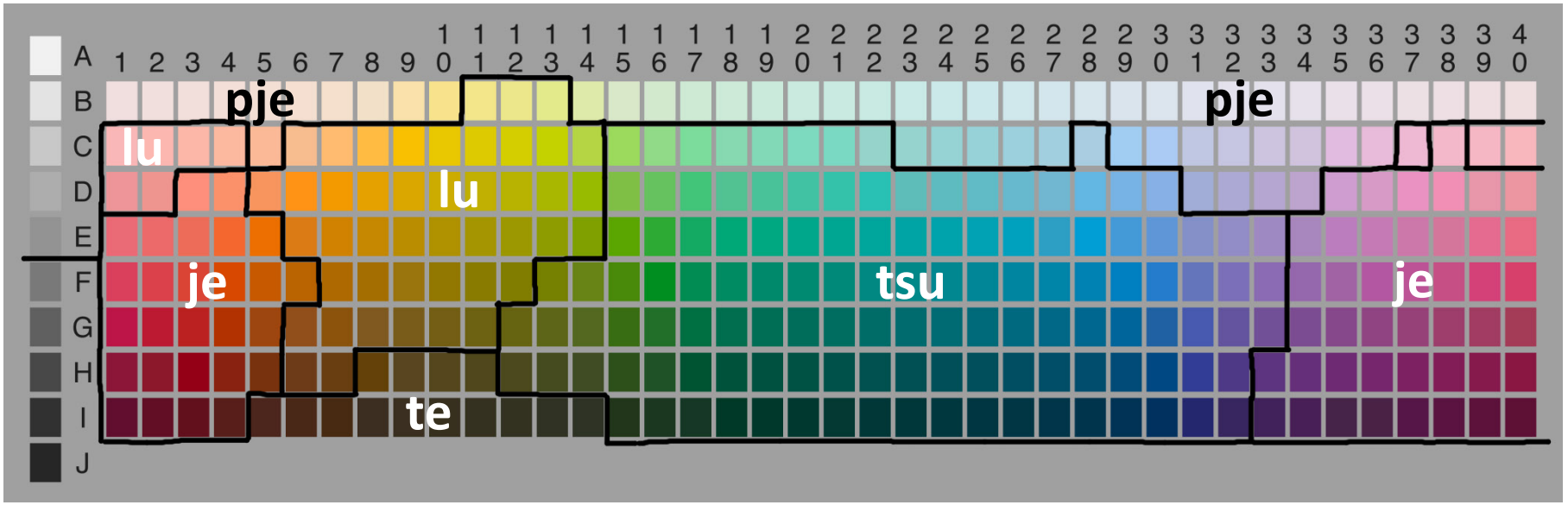
4 BCT - example



Karajá (Brazil)

This is a rare pattern, but not unique: light, dark, red, non-red

5 BCT - example

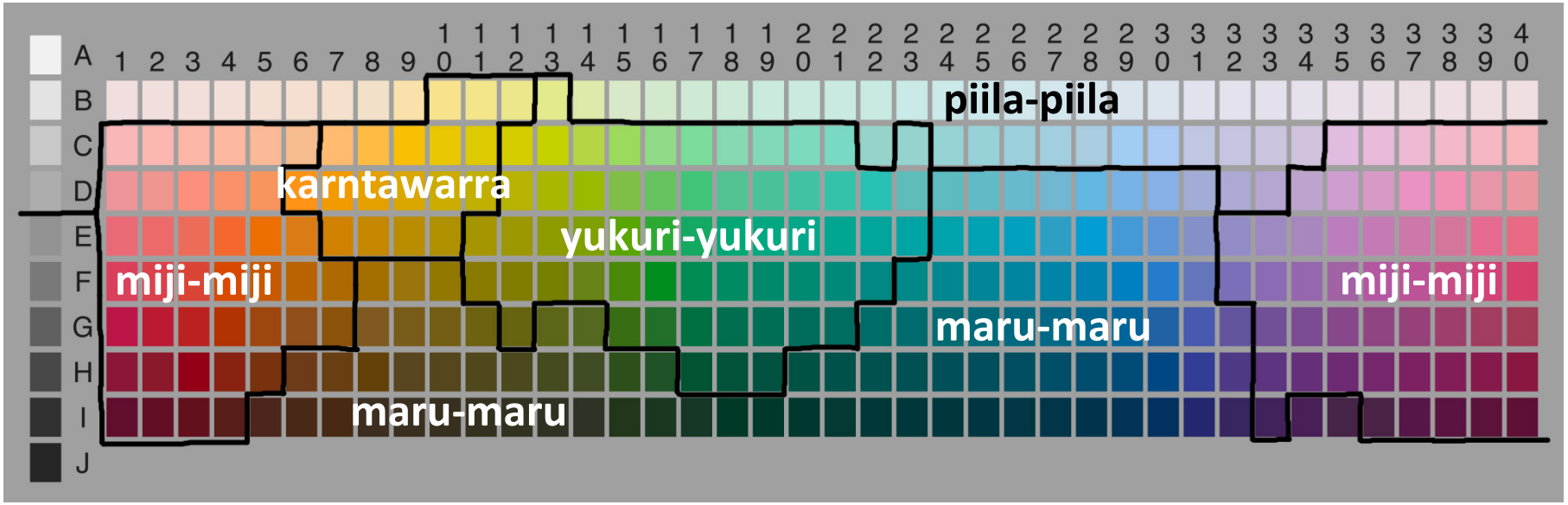


Jicaque (Honduras)

*This is a common 5 BCT pattern, using **grue***

Ex: Celtic languages, Zulu, old Japanese

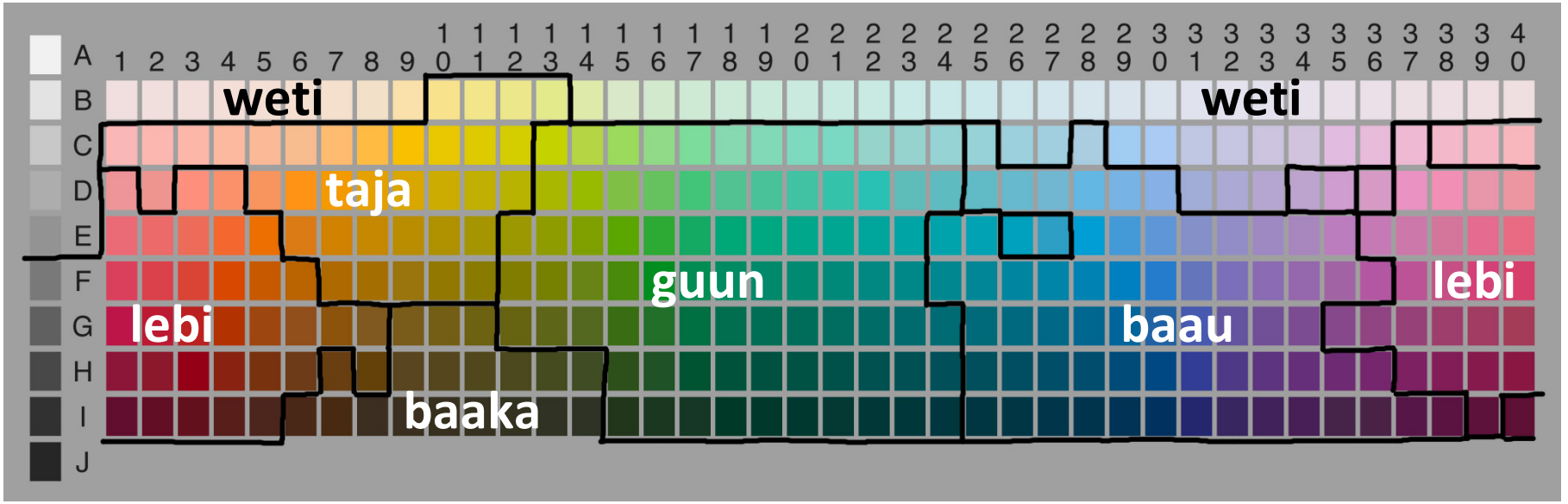
5 BCT - example



Martu Wangka (Australia)

This is also how Vikings talked –
calling Africa Blåland (blue country) and Africans Blåmän (blue men)

6 BCT example



Djuka (Surinam) (a creole including Dutch)

All Urfarben are BCTs!

Language similarities

Thus, for languages with few BCT the foci and ranges are remarkably similar.

Conclusion: The three colour channels in the optic nerve leads to regularities in colour naming.

For languages with more than 6 BCT the Urfarben are always present, but there is very little further regularity.

Three colour naming confusors

Language differences

Brain differences

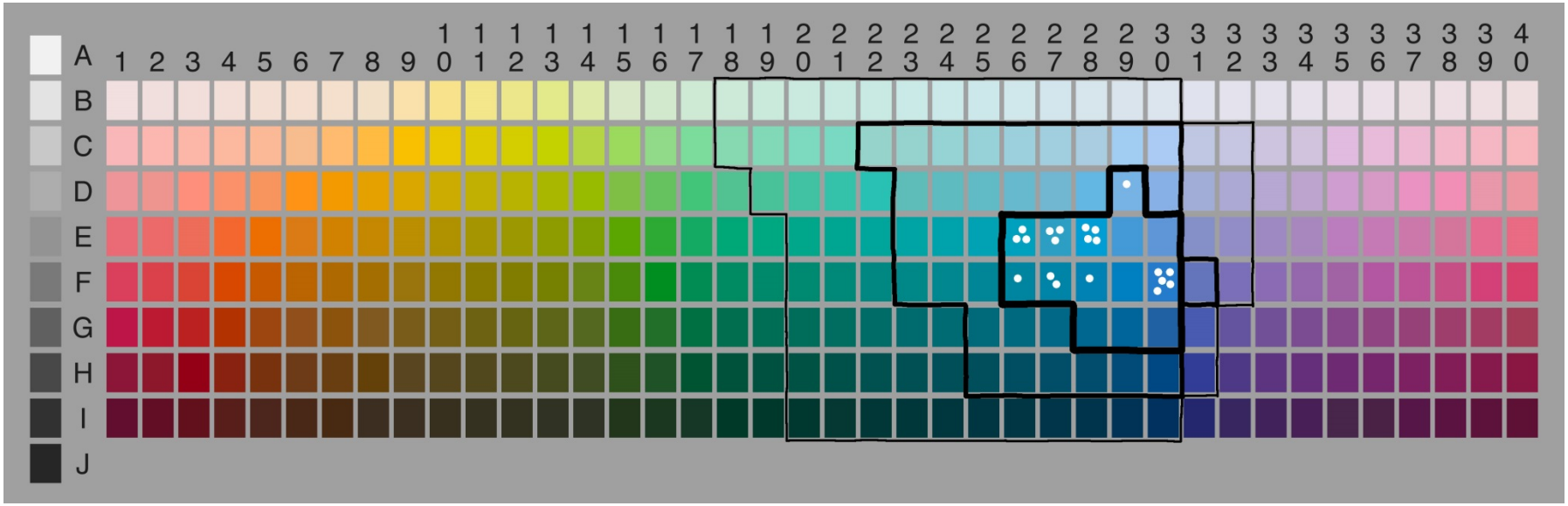
Individual differences

Brain differences

Experiments – not involving colour **naming** – show clearly measurable differences depending on mother tongue.

- Speed of distinguishing within and between BCTs (English and Russian)
- Speed of distinguishing different in left (language) and right hemisphere (English)
- Speed of determining colour equality between BCTs and non-BCTs (Chinese)

Individual differences



The foci and ranges of “blue” of 20 speakers of Indo-European languages

The lines represent: AND, half, and OR ranges.

Colour name categories

1. BCT (grey)
2. qualified BCT (dark grey)
3. qualified fancy (lead grey)
4. fancy (marengo)

These are used when investigating the richness of individual colour names.

Individual differences

Swedish FOA study 1995 by Gunilla Derefeldt

Purpose: How many colours can you remember?
Answer: About 30 – *if the subjects could name them freely*

Serendipitous for us – the **names** used!

Individual differences

Swedish FOA study 1995 by Gunilla Derefeldt

Almost no BCT (brown) or qualified BCT (light red)

Mostly qualified fancy (thunder blue, flag blue, pigeon blue)

Some fancy (jade, plum, cerise)

Very little agreement between testees.

Individual differences

1977 Colour naming experiment in USA using 25 colour chips
Males and Nuns: mostly BCT and qualified BCT
Worldly Females: mostly qualified fancy and fancy

Other studies gave similar results

Conclusion: women have better colour vision than men

but...

Individual differences

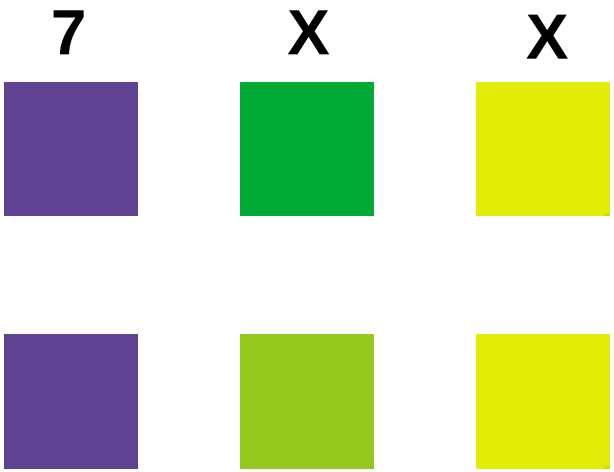
1995, 2002 USA studies of young people:
No sex differences

Same mistake as thinking “primitive” people are colour blind:

Few names $\not\Rightarrow$ colour blind

Many names $\not\Rightarrow$ better colour vision

but...

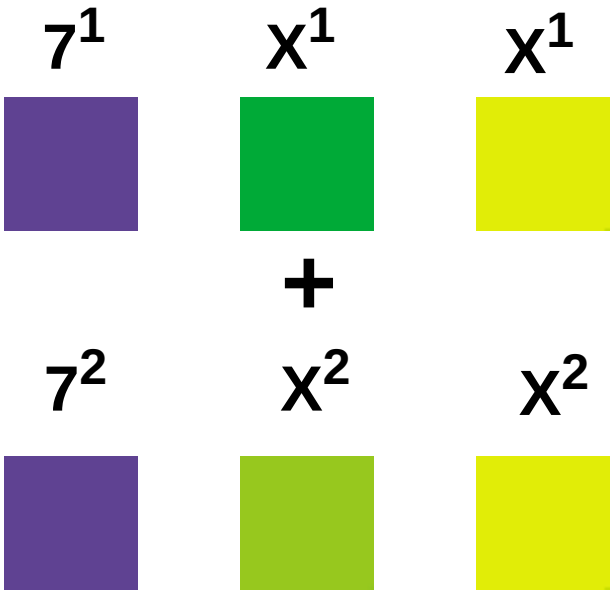


Chromosome with opsin gene

Normal colour vision

Deuteranomaly – *most common*

Human tetrachromates?



Normal colour vision

Deuteranomaly

⇒ woman with **four** different opsins

but can they be used?

Mouse trichromates!

Wild mouse

Modified mouse

Human **L**

⇒ trichromatic mouse!

Human tetrachromate

If the mouse brain can do it, so can hers!

Don’t quarrel!

The cone pattern in your retina influences your colour perception

Your mother tongue influences your colour perception

Your mother tongue influences your colour naming

Your culture influences your colour naming

Your experience influences your colour naming

Because...

What is **cerulian** to an Artist (a specific pigment)

is **goluboy** to a Russian (light blue)

is **blue** to an Englishman (blue)

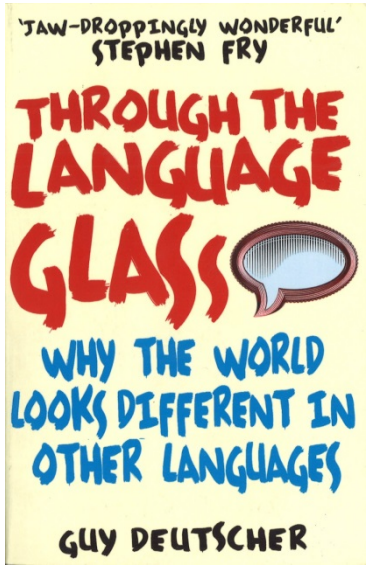
is **-luhlaza** to a Zulu (blue+green)

is **nukin** to a Chukchi (black+green+blue)

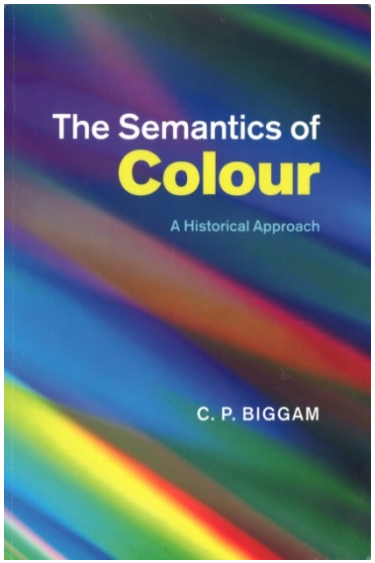
is **mili** to a Dani (all dark, cold colours)

and it can't be shown on an RGB screen!

Sources



Prof. Leiden U.



Lect. Glasgow U.

http://www.cb.uu.se/~gunilla/Colours

Ögonblick i färg (on colour vision, in Swedish)
Choosing colours for data presentation
This presentation

Prof.em. UU*

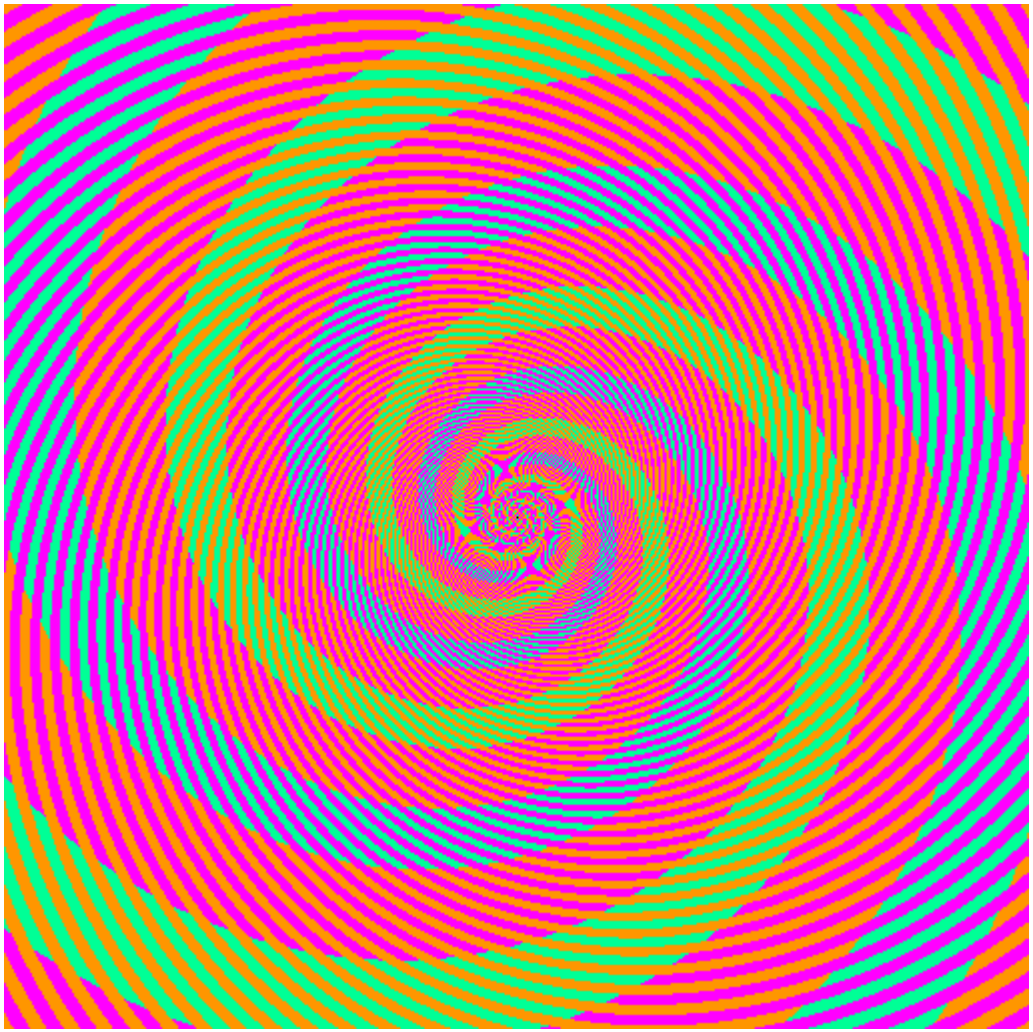
*not Unseen University

Best vision system known belongs to birds that hunt moving prey.

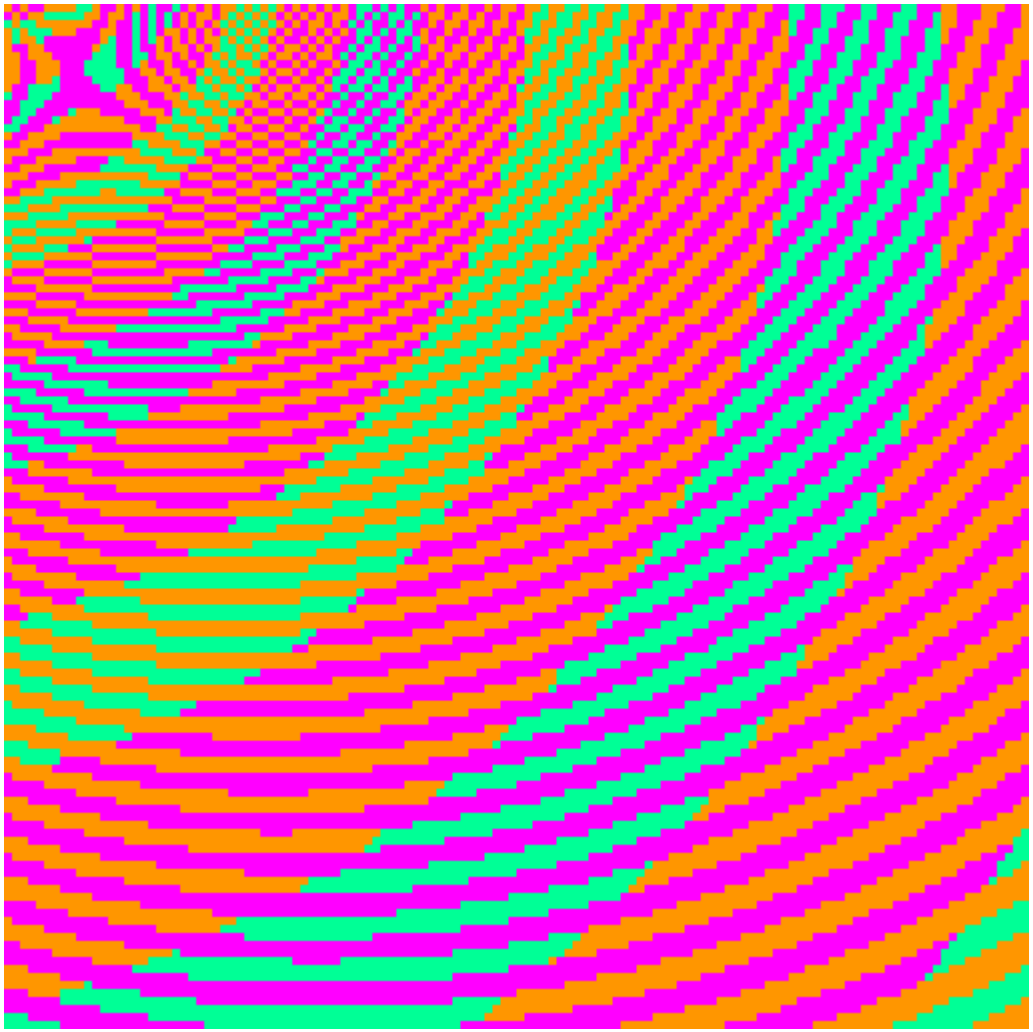
The End!

Dragonflies have the best invertebrate eyes – for the same reason.

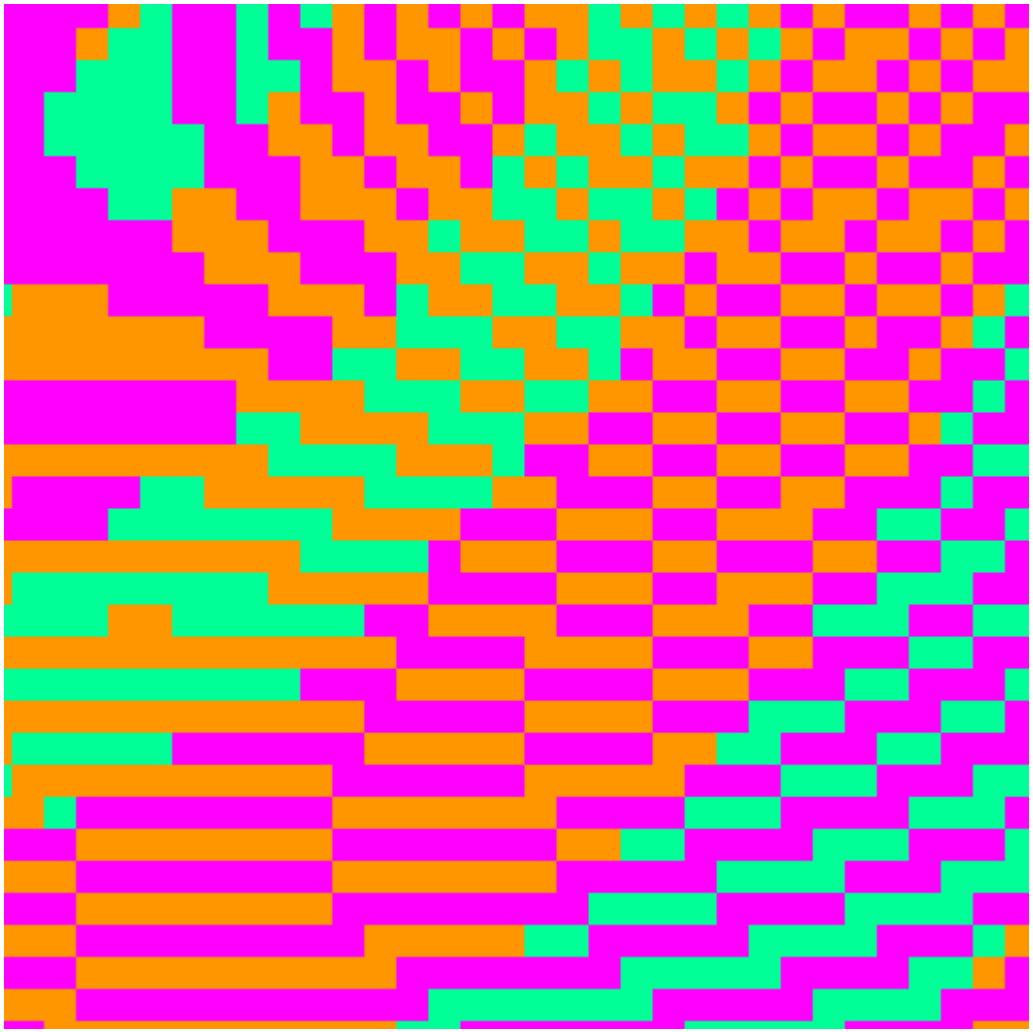
How many colours?



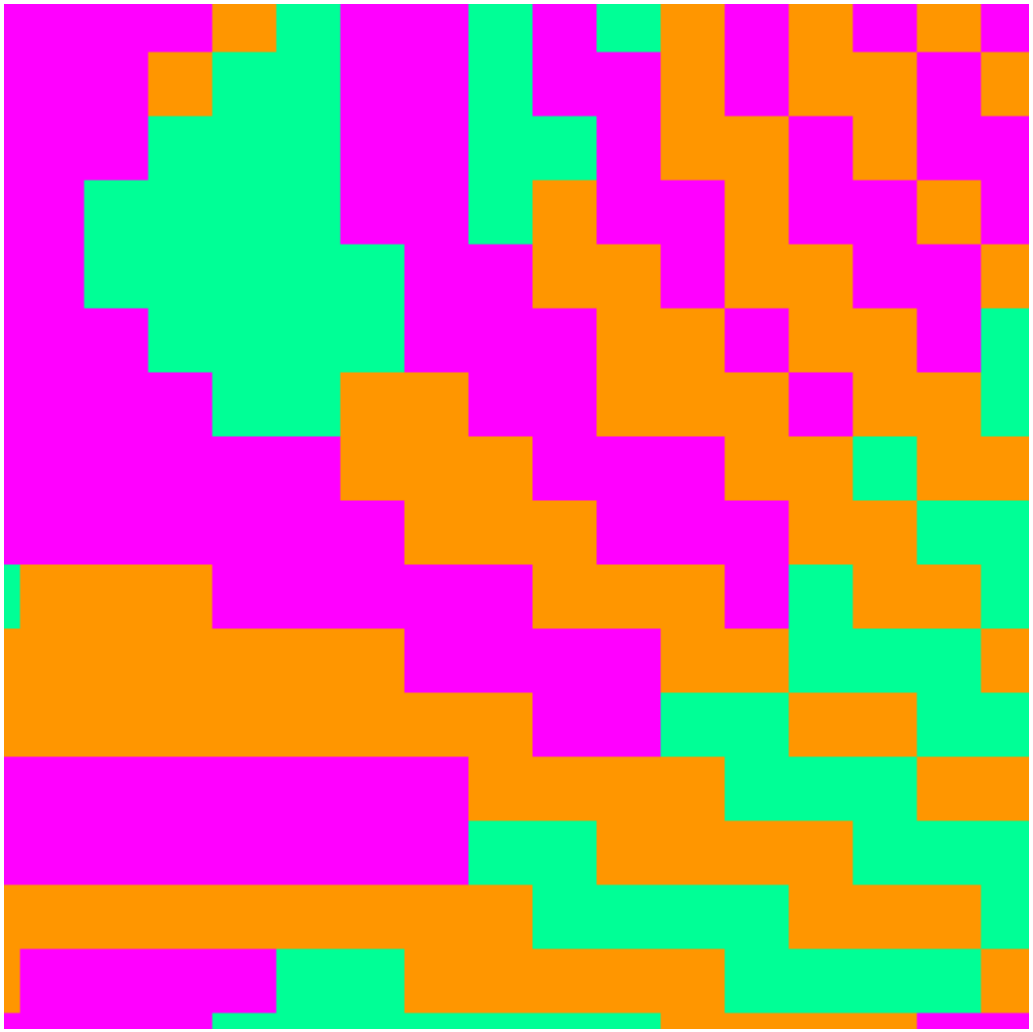
How many colours?



How many colours?



How many colours?



Only 3 –
but that is another perception story!