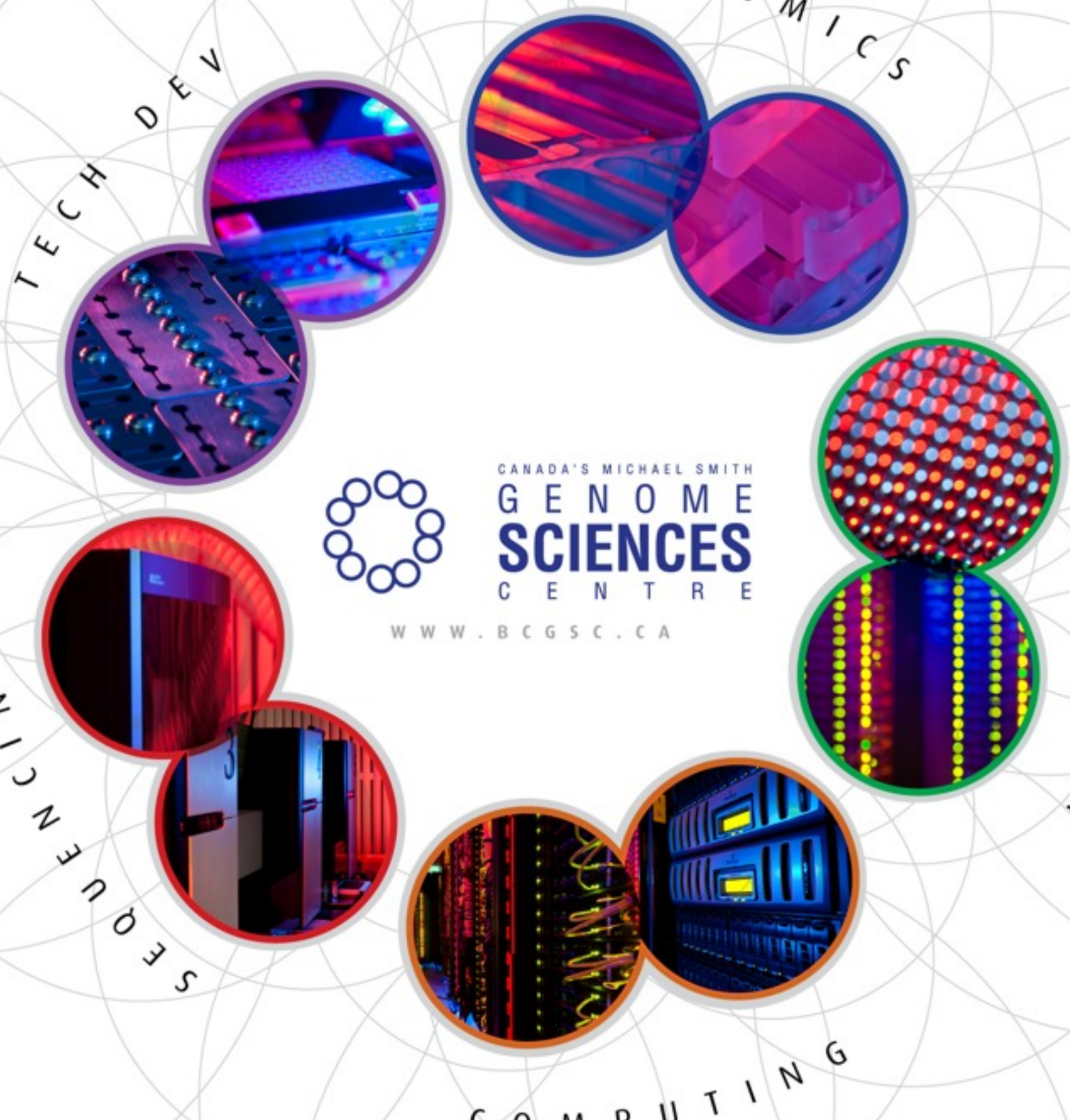

CANADA'S MICHAEL SMITH
GENOME
SCIENCES
CENTRE

WWW.BCGSC.CA

AFFILIATIONS BC Cancer Research Center • BC Cancer Agency • BC Cancer Foundation • Genome BC • Simon Fraser University • University of Britsh Columbia • Genome Sciences Institute

designing effective visualizations in the biological sciences

13.00 - 14.00

MARTIN KRZYWINSKI
Genome Sciences Center
BC Cancer Agency
Vancouver, Canada

PSA ANNUAL MEETING 2011
GENOMICS WORKSHOP
University of Washington
12 July 2011

BC Cancer Agency
CARE + RESEARCH

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design : effective visual communication

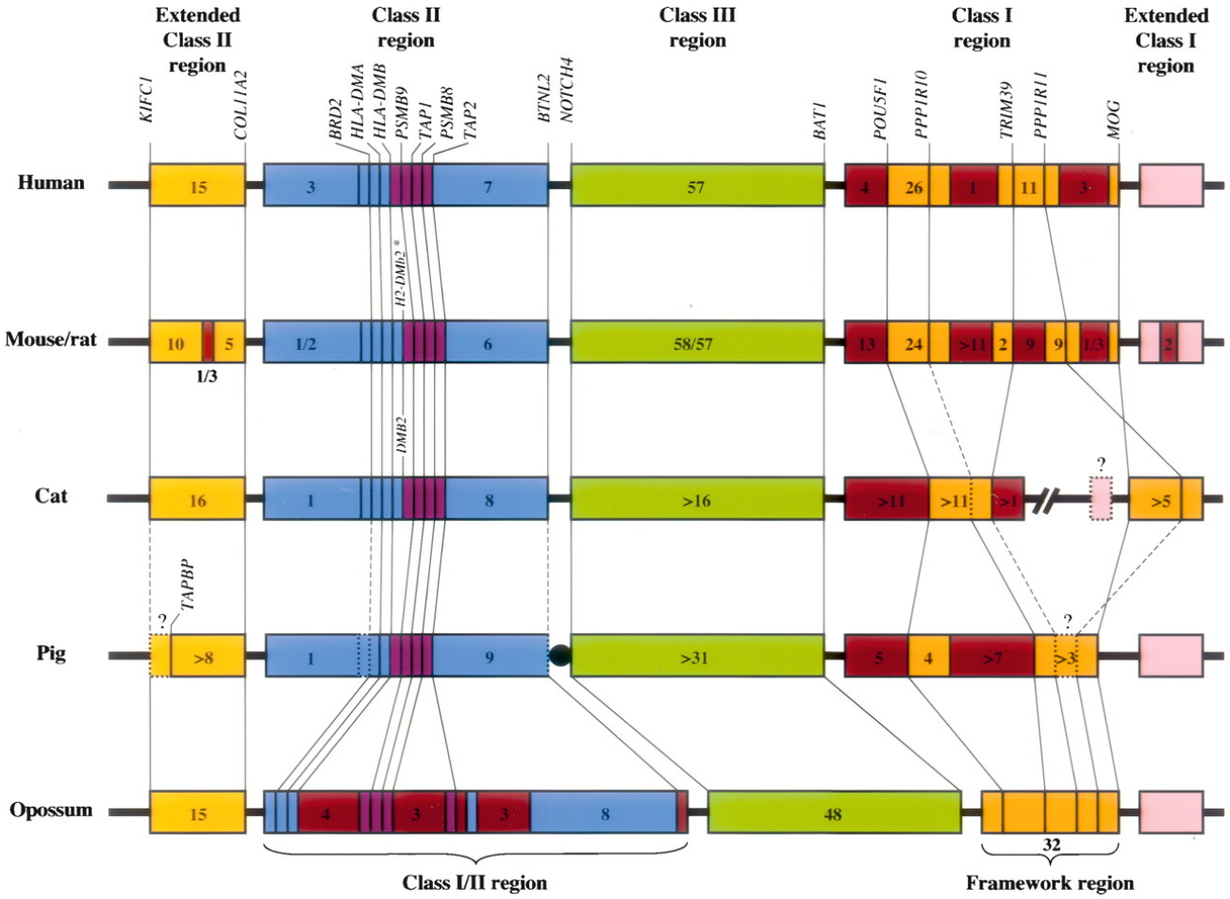
OBJECTIVE

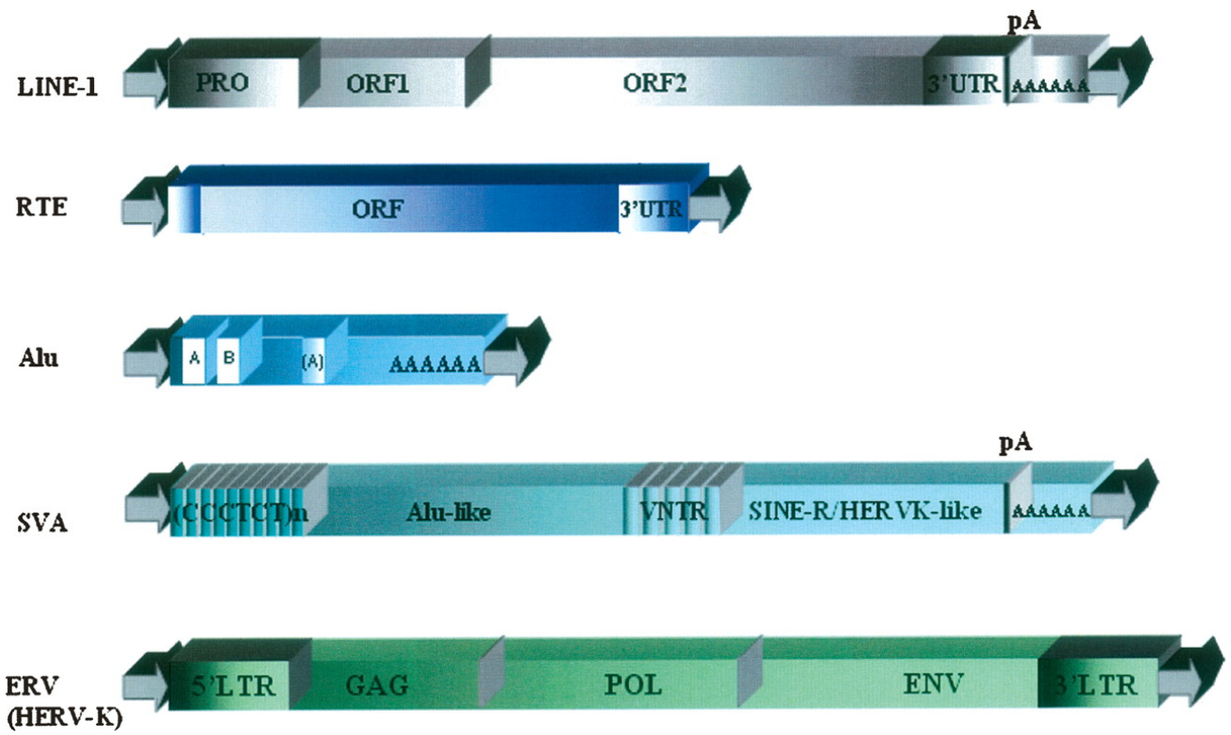
FOLLOWING GUIDELINES

SUBJECTIVE

BREAKING GUIDELINES PURPOSEFULLY

OBJECTIVE ASPECTS OF CLEAR COMMUNICATION





Excellent organization and consistency. Clear use of color. Vertical lines cue continuity.

Samollow, P.B., The opossum genome: insights and opportunities from an alternative mammal. Genome Res, 2008. 18(8): p. 1199-215.

Overly ornamental. Illegible and inconsistently formatted text. Redundant elements.

Gentles, A.J., et al., Evolutionary dynamics of transposable elements in the short-tailed opossum Monodelphis domestica. Genome Res, 2007. 17(7): p. 992-1004.

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OBJECTIVE ASPECTS OF ATTRACTION

Healthy coat. Pleasant colour scheme. Vigorously adorable proportions. Attentive gaze. Sympathetic eyes.

Where do I start?

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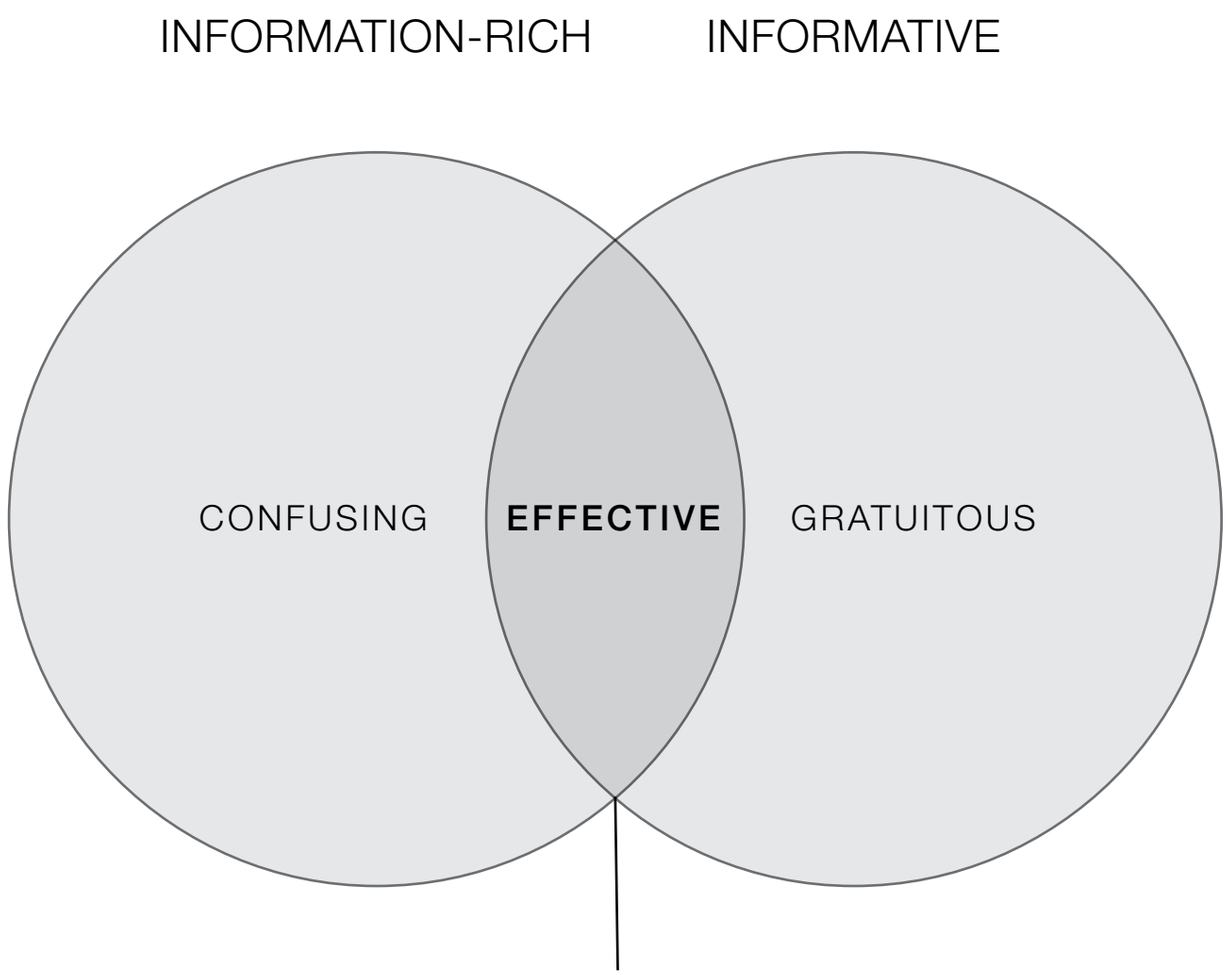
WHAT IS AN EFFECTIVE VISUALIZATION?



CLEAR MESSAGE

HIGH DATA-TO-INK RATIO

ACCESSIBLE COMPLEXITY

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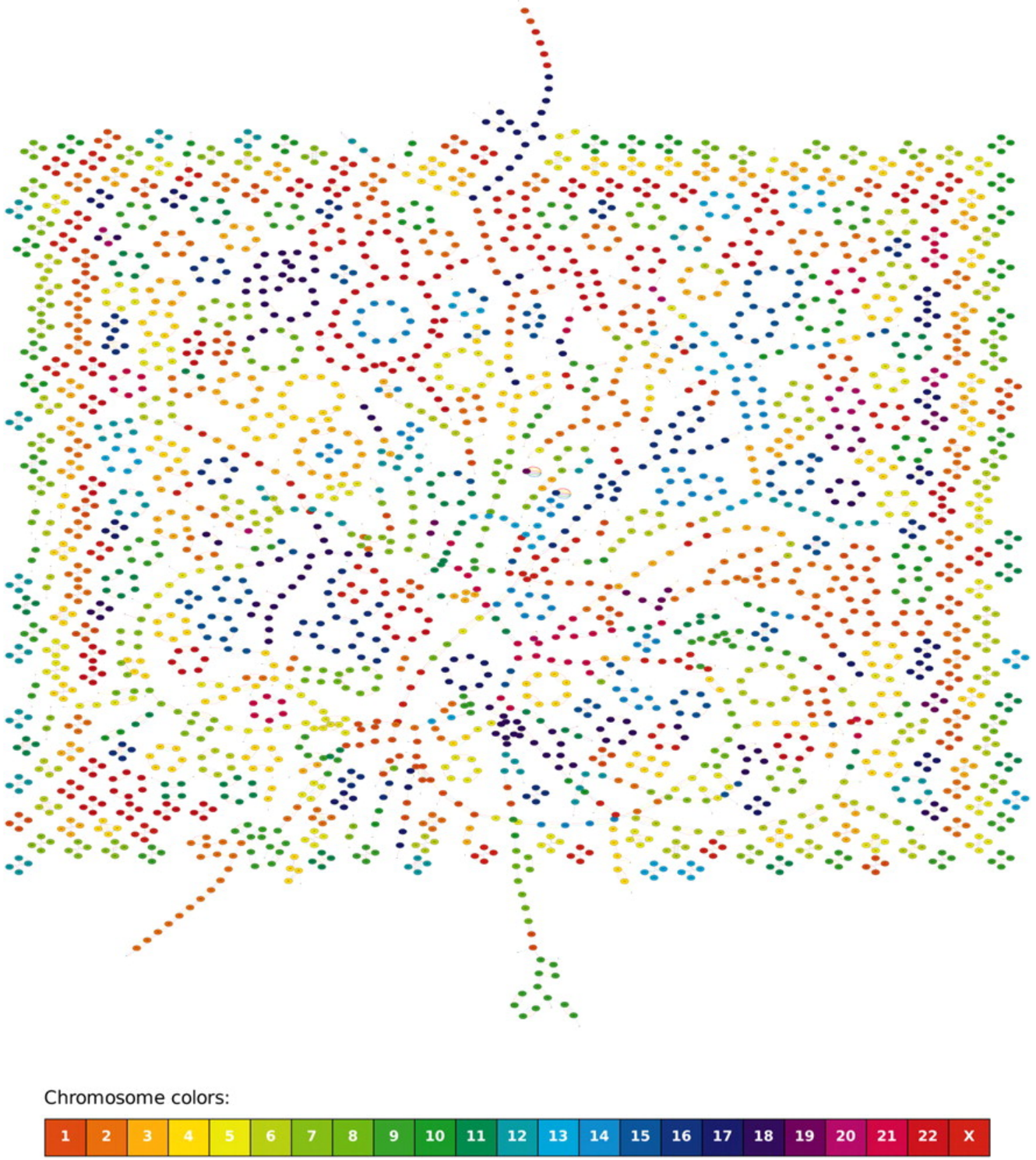
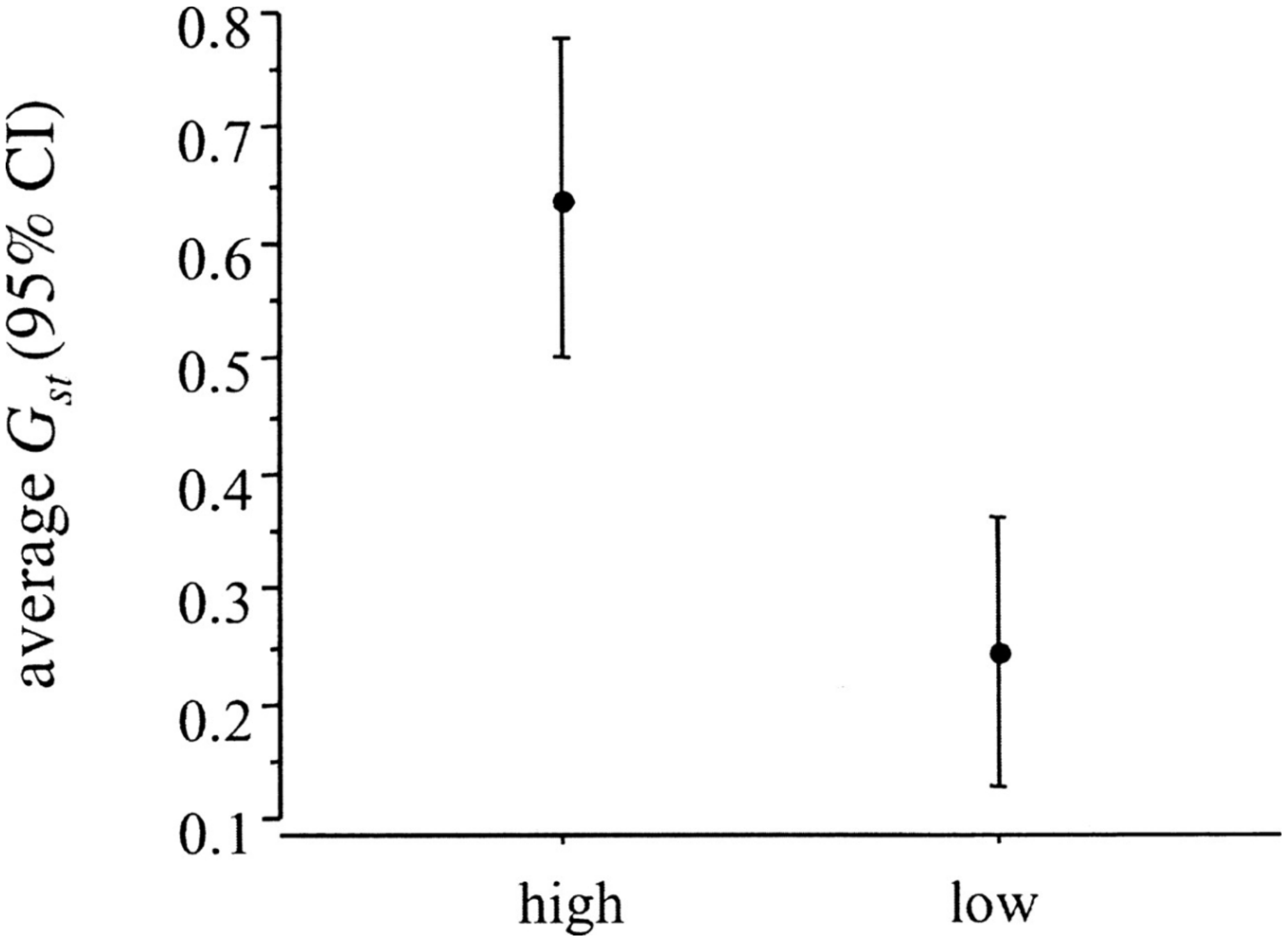
INFORMATION-RICH, NOT INFORMATIVE



The breakspoint graph G(M,R,D,Q,H,C) (obverse edges are not shown) of six mammalian genomes. Alekseyev, M.A. and P.A. Pevzner, Breakpoint graphs and ancestral genome reconstructions. Genome Res, 2009. 19(5): p. 943-57.

INFORMATIVE, NOT INFORMATION-RICH



Mean and 95% confidence interval of average Gst based on direct sequencing of fragments within high (N = 8) and low (N = 6) differentiation regions in natural population of house mice. Harr, B., Genomic islands of differentiation between house mouse subspecies. Genome Res, 2006. 16(6): p. 730-7.

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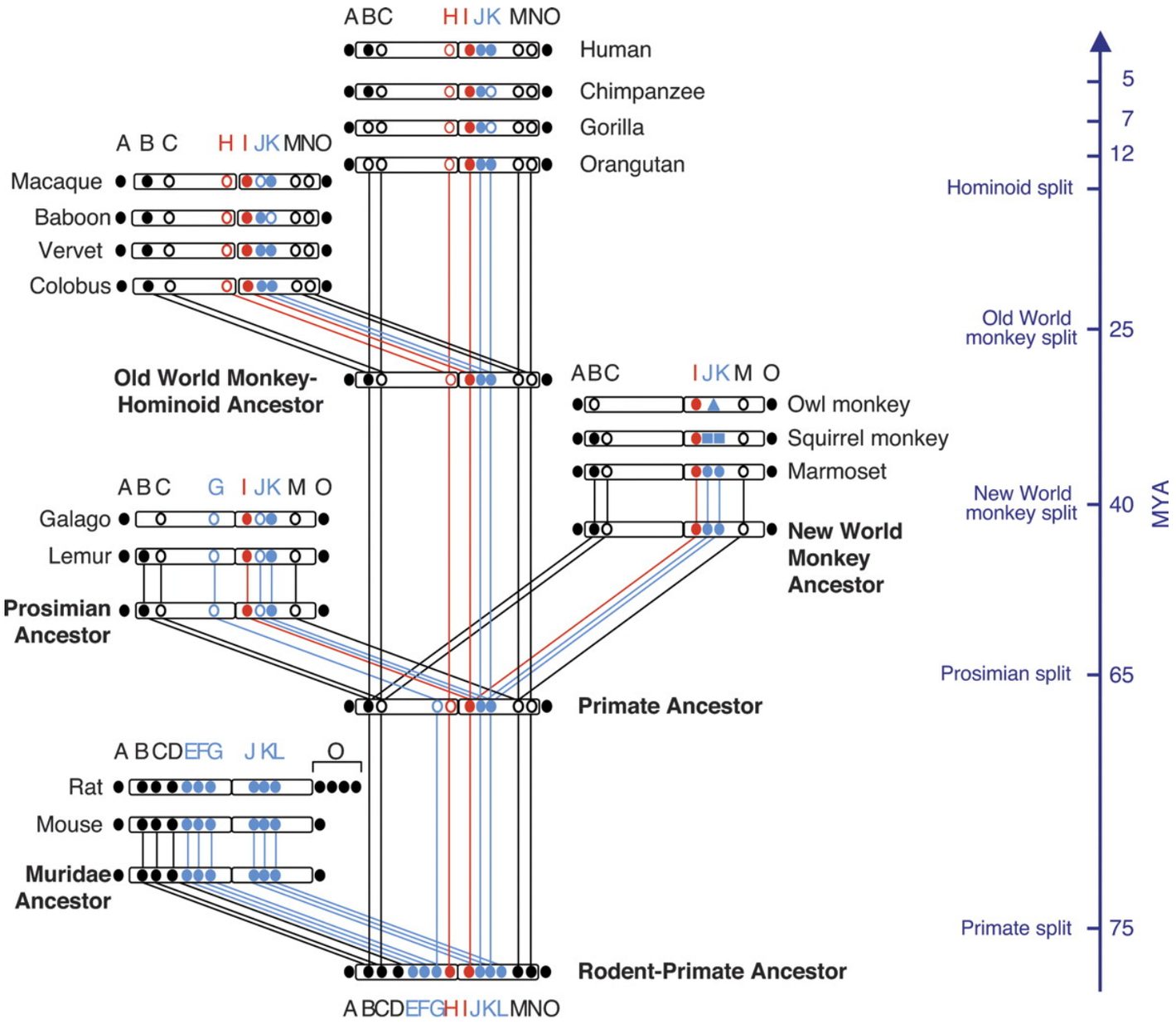
INFORMATION-RICH AND INFORMATIVE



A *WFDC5/Wfdc5*	**D** *WFDC15a/Wfdc15a*	**M** *WFDC15c/Wfdc15c*
B *WFDC12/Wfdc12*	**E, F, G, J, K, L** *SEMG/Svs* family	**N** *WFDC15d/Wfdc15d*
C *WFDC15b/Wfdc15b*	**H, I** Trappin (*PI3*) family	**O** *SLPI/Slpi* family

Evolutionary history of the centromeric WFDC sublocus. Hurle, B., W. Swanson, and E.D. Green, Comparative sequence analyses reveal rapid and divergent evolutionary changes of the WFDC locus in the primate lineage. Genome Res, 2007. 17(3): p. 276-86.

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requirements for effective visual communication

LEGIBILITY

CLARITY

AND OPTIONALLY,

ATTRACTIVENESS

LEGIBLE

are all elements discernable?

does text contrast well with background?

is there simultaneous contrast?

RESOLUTION

PARSABILITY

COLOR

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LEGIBLE

are all elements discernable?

does text contrast well with background?

is there simultaneous contrast?

CLEAR

does the reader see the **noise** or **trends**?

message delivered?

are there redundant or ornamental elements?

RESOLUTION
PARSABILITY
COLOR

STRONG MESSAGE
EXCESS INK
REDUNDANCY
GLYPHS
OUTLIER HIJACK

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LEGIBLE

are all elements discernable?

does text contrast well with background?

is there simultaneous contrast?

CLEAR

does the reader see the **noise** or **trends**?

message delivered?

are there redundant or ornamental elements?

ATTRACTIVE

are spacing and orientation of visual cues consistent?

RESOLUTION
PARSABILITY
COLOR

STRONG MESSAGE
EXCESS INK
REDUNDANCY
GLYPHS
OUTLIER HIJACK

GRID LAYOUT

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LEGIBLE

are all elements discernable?

does text contrast well with background?

is there simultaneous contrast?

CLEAR

does the reader see the **noise** or **trends**?

message delivered?

are there redundant or ornamental elements?

ATTRACTIVE

are spacing and orientation of visual cues consistent?

DO I HAVE A MESSAGE ? HAVE I COMMUNICATED IT ?

RESOLUTION
PARSABILITY
COLOR

STRONG MESSAGE
EXCESS INK
REDUNDANCY
GLYPHS
OUTLIER HIJACK

GRID LAYOUT

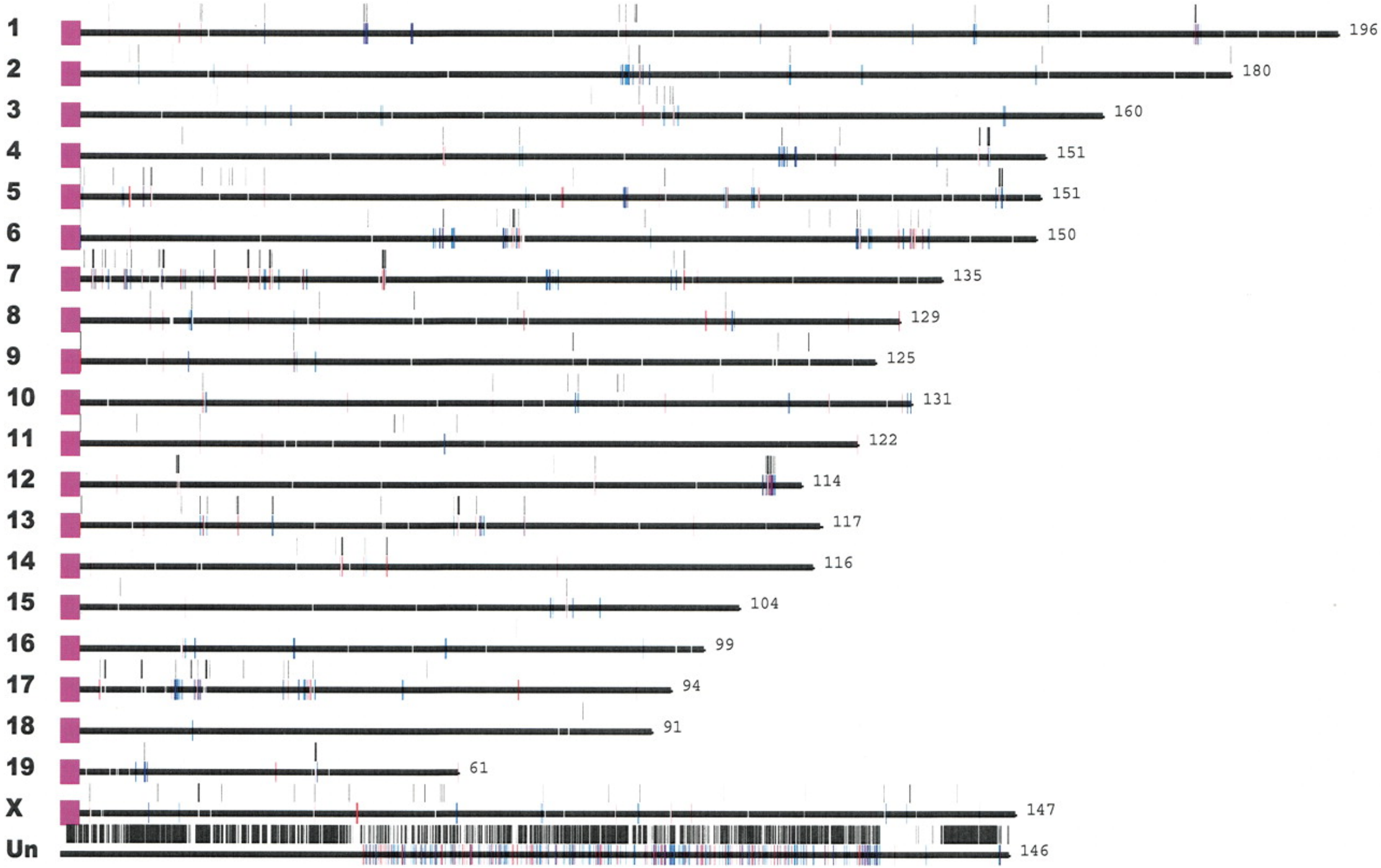
legibilityclarityattractiveness

RESOLUTION

PARSABILITY

COLOR

RESOLUTION & ACUITY LIMITS



Mouse segmental duplications. J. A. Bailey, D. M. Church, M. Ventura, M. Rocchi, E. E. Eichler, Genome Res 14, 789 (May, 2004).

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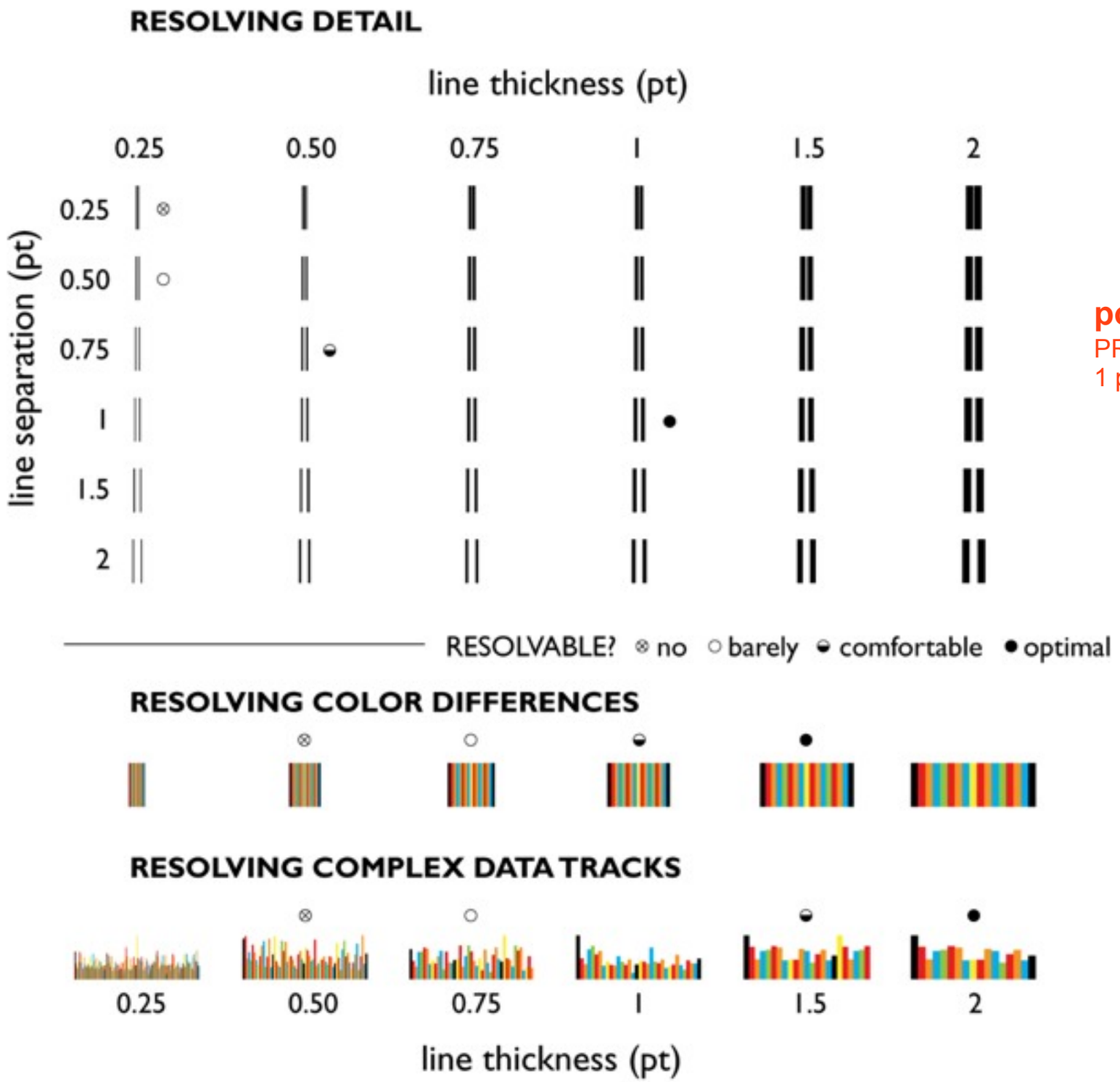
RESOLUTION & ACUITY LIMITS



point
PRINT LENGTH UNIT
1 pt = 1/72 inch

The resolving power of the eye is approximately 50 cycles per degree. This limits us from distinguishing features smaller than 0.1 mm at a reading distance of 30 cm. Larger features must be used to maintain legibility and comprehension. 1 point = 1/72 inch = 0.0353 cm

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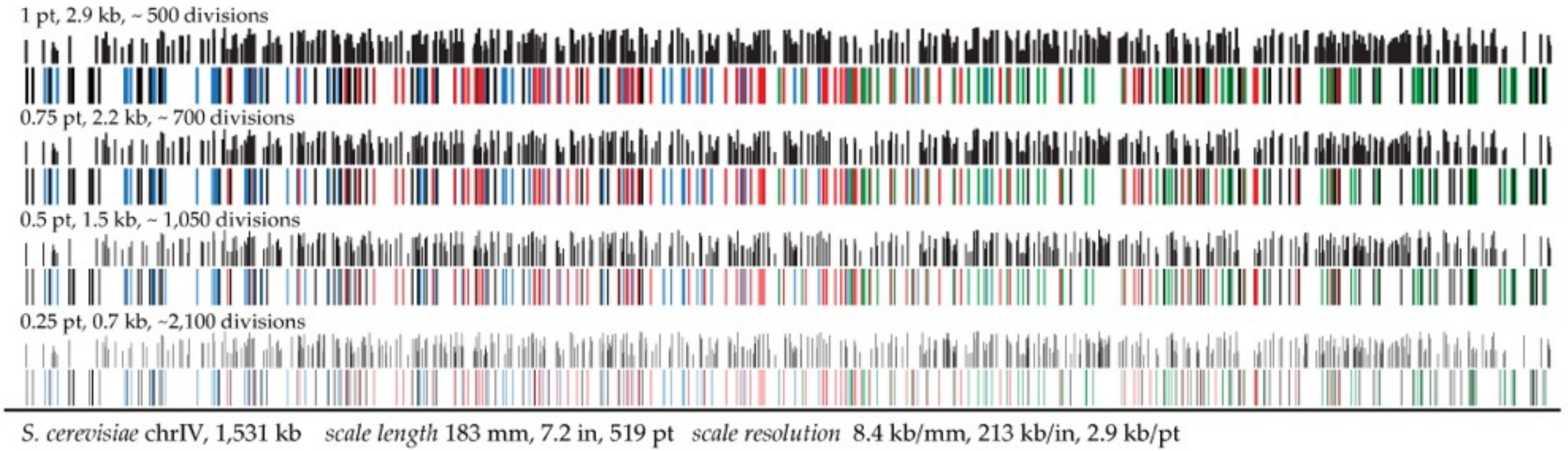
RESOLUTION & ACUITY LIMITS

DO NOT DIVIDE YOUR SCALE INTO MORE THAN 500 INTERVALS



As a rule of thumb, you should not divide your scale into more than 500 intervals per 8.5 inch (216mm, US letter size). This corresponds to 1 pt on a 183 mm figure, 4 pixels on a 1920 horizontal resolution display, or 2 pixels on a typical LCD projector.

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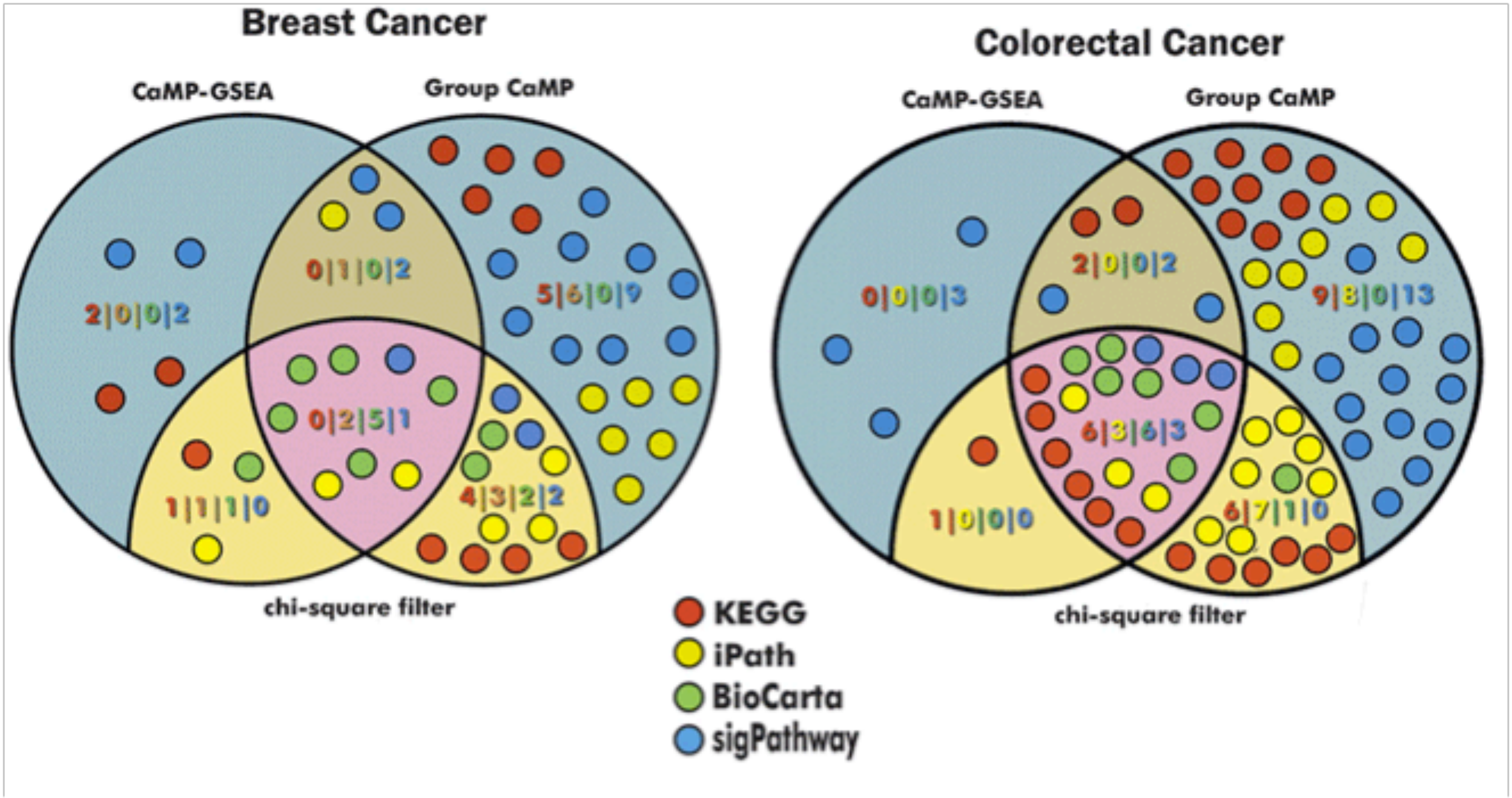
PARSABILITY LIMITS

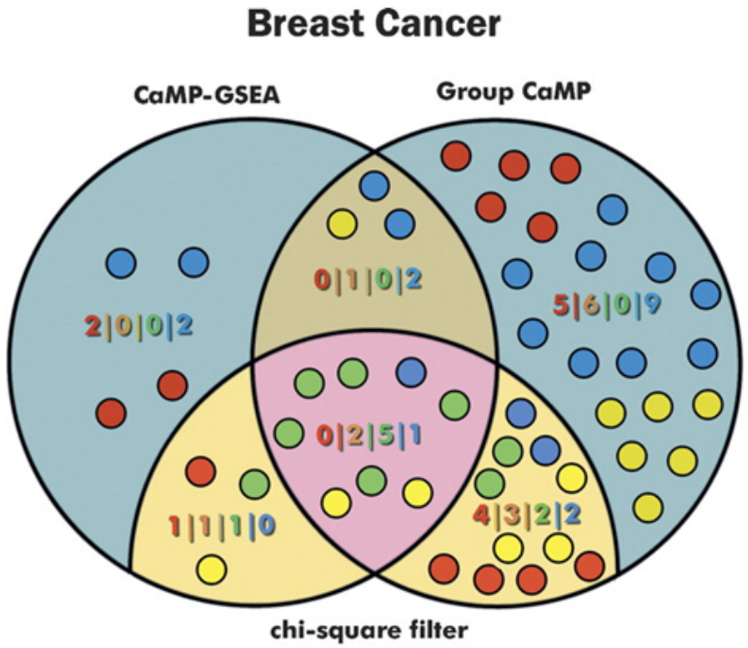
The specific domains and combinations in the domain graph. Ye, Y. and A. Godzik, Comparative analysis of protein domain organization. Genome Res, 2004. 14(3): p. 343-53.

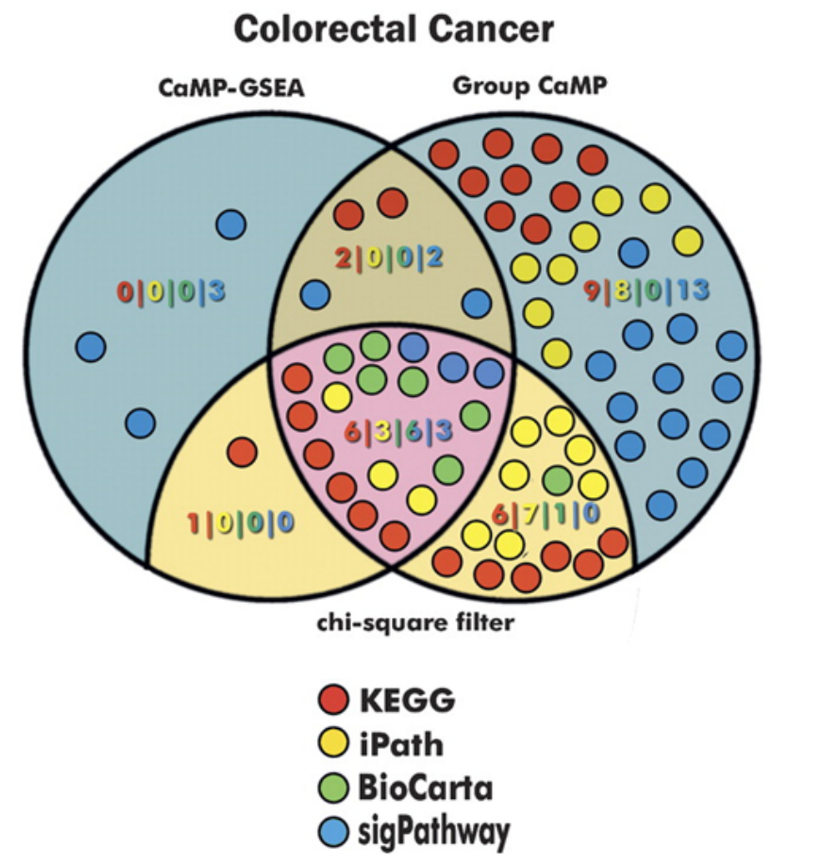
PARSABILITY LIMITS

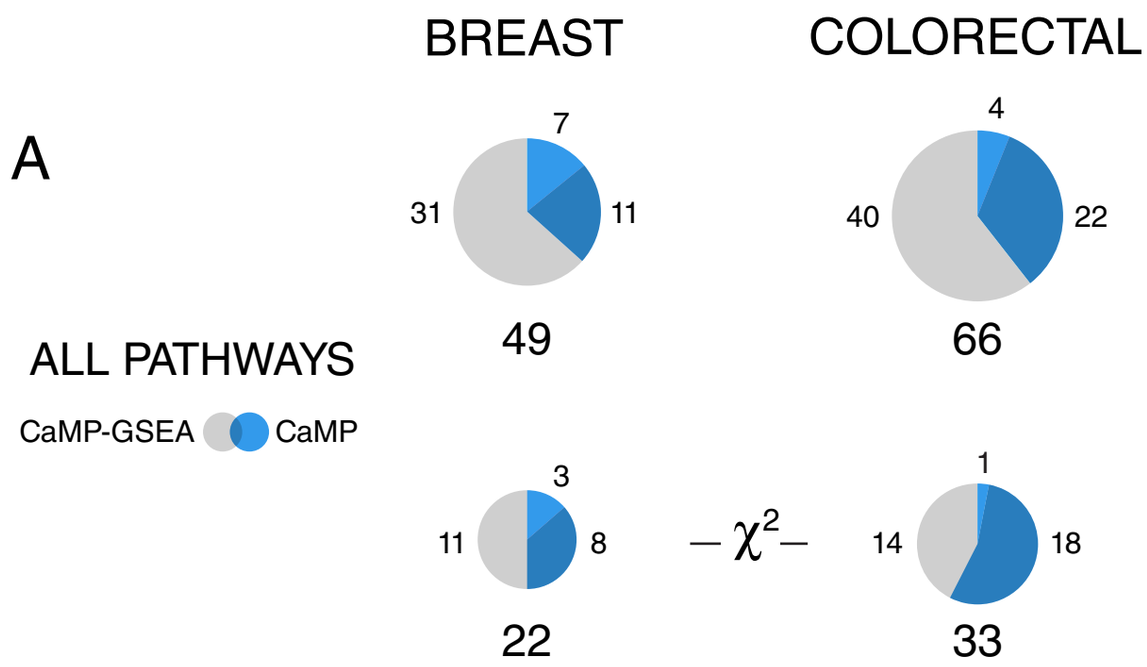


Comparison of mutation enrichment in cellular pathways using complementary statistical approaches. Lin, J., et al., A multidimensional analysis of genes mutated in breast and colorectal cancers. Genome Res, 2007. 17(9): p. 1304-18.

REFACTORING COMPLEXITY







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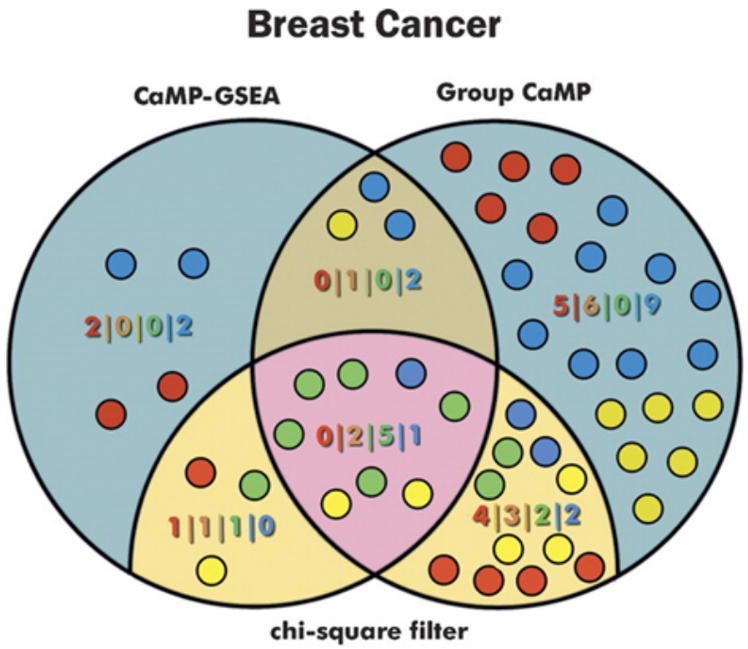
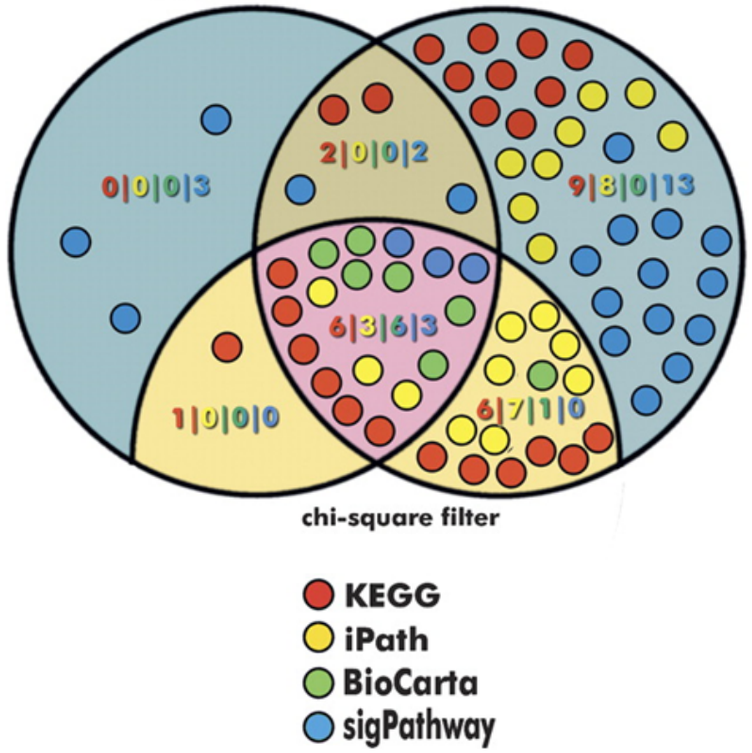
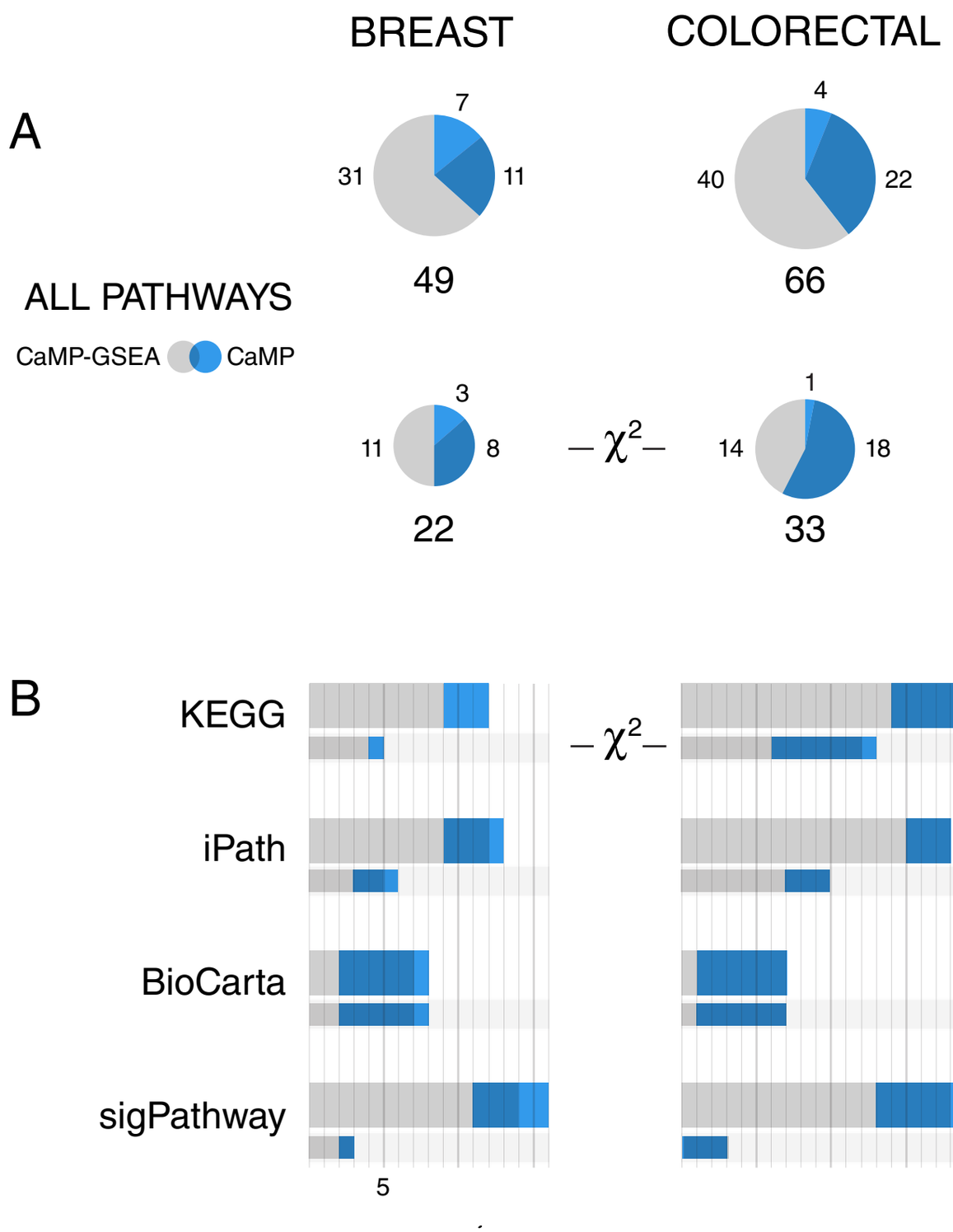
REFACTORING COMPLEXITY







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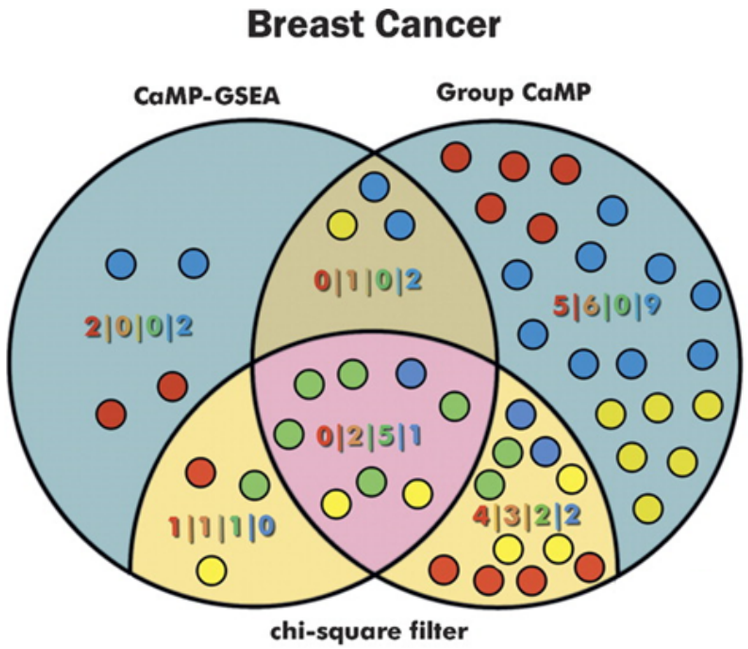
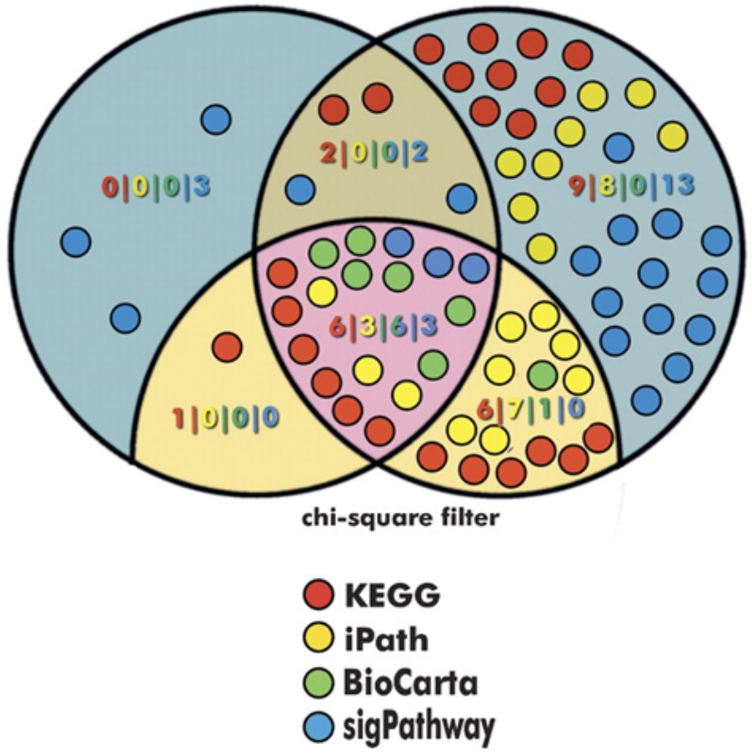
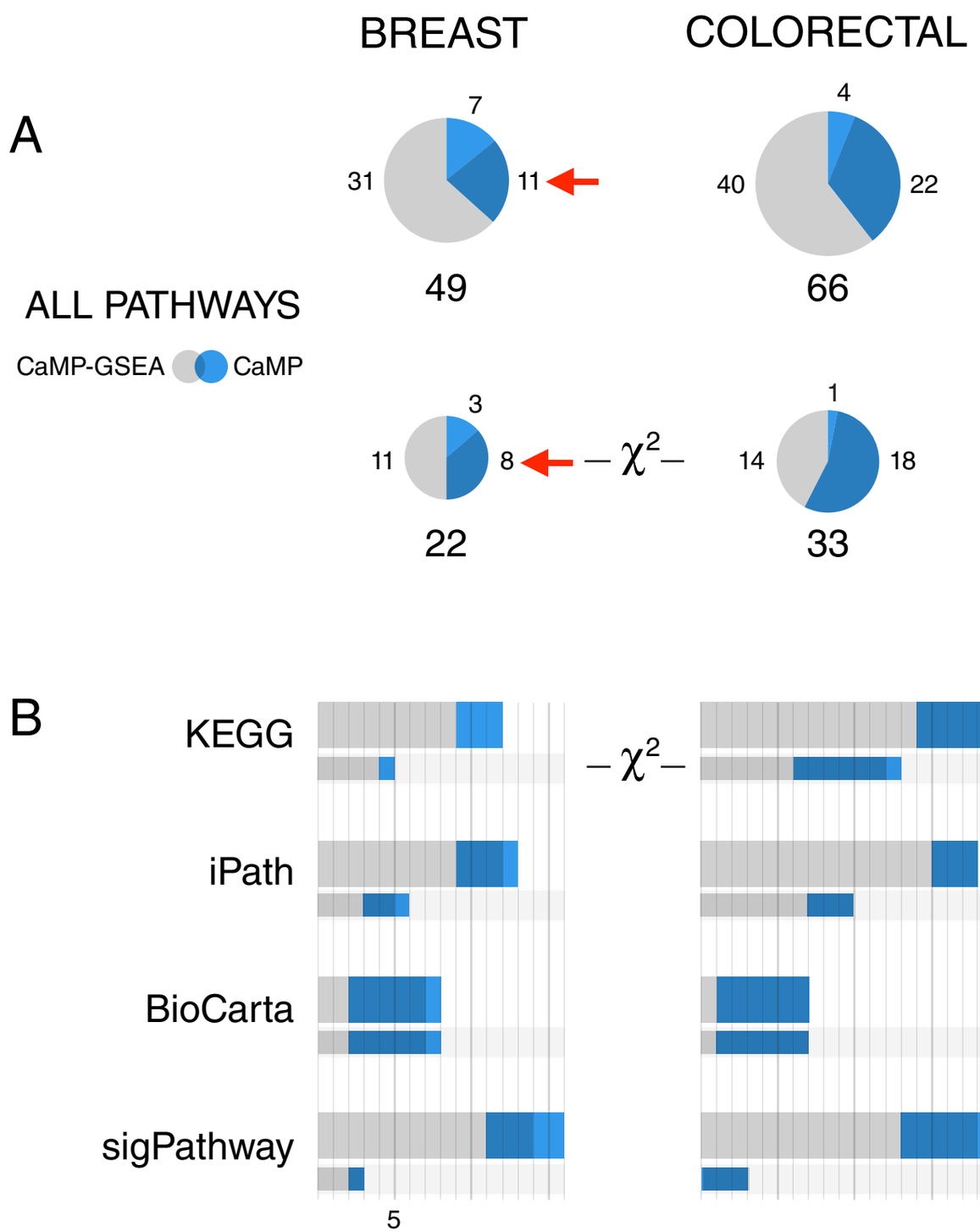
REFACTORING COMPLEXITY







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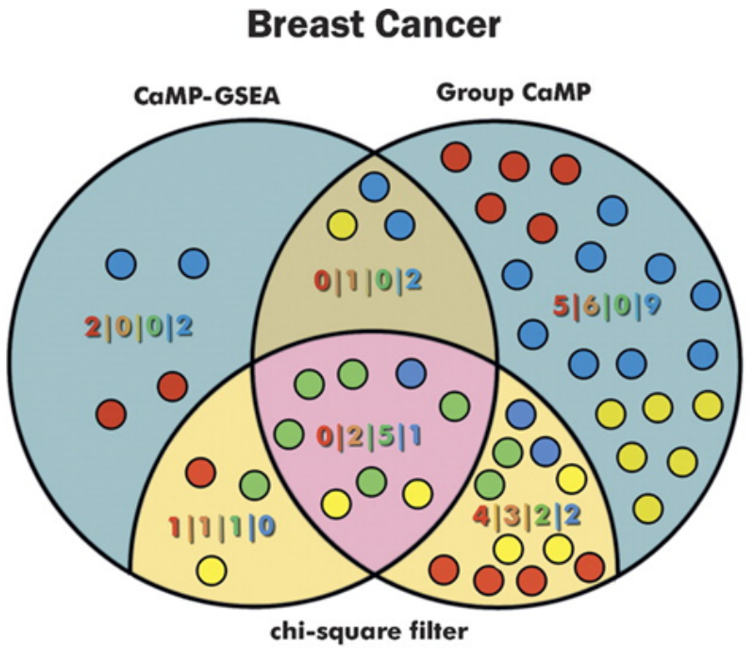
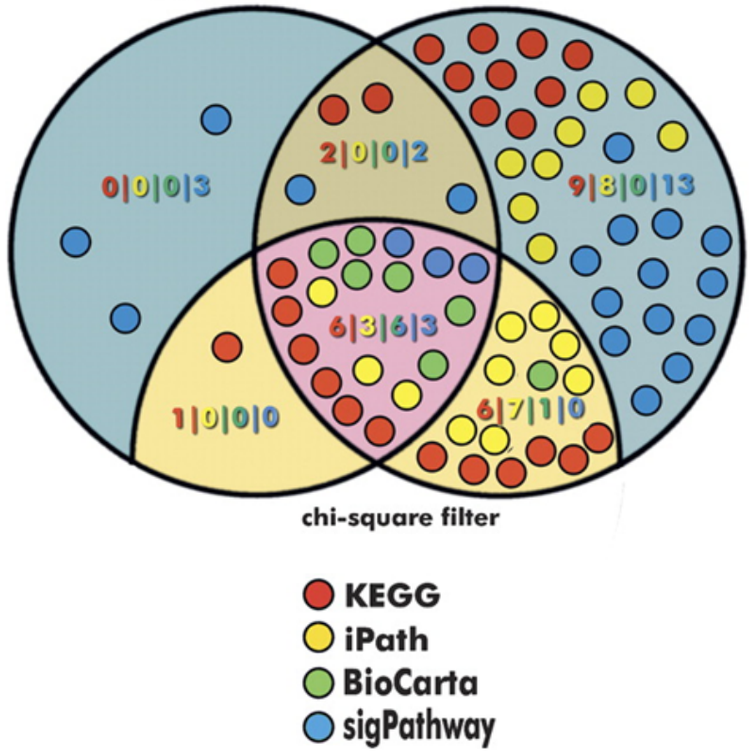
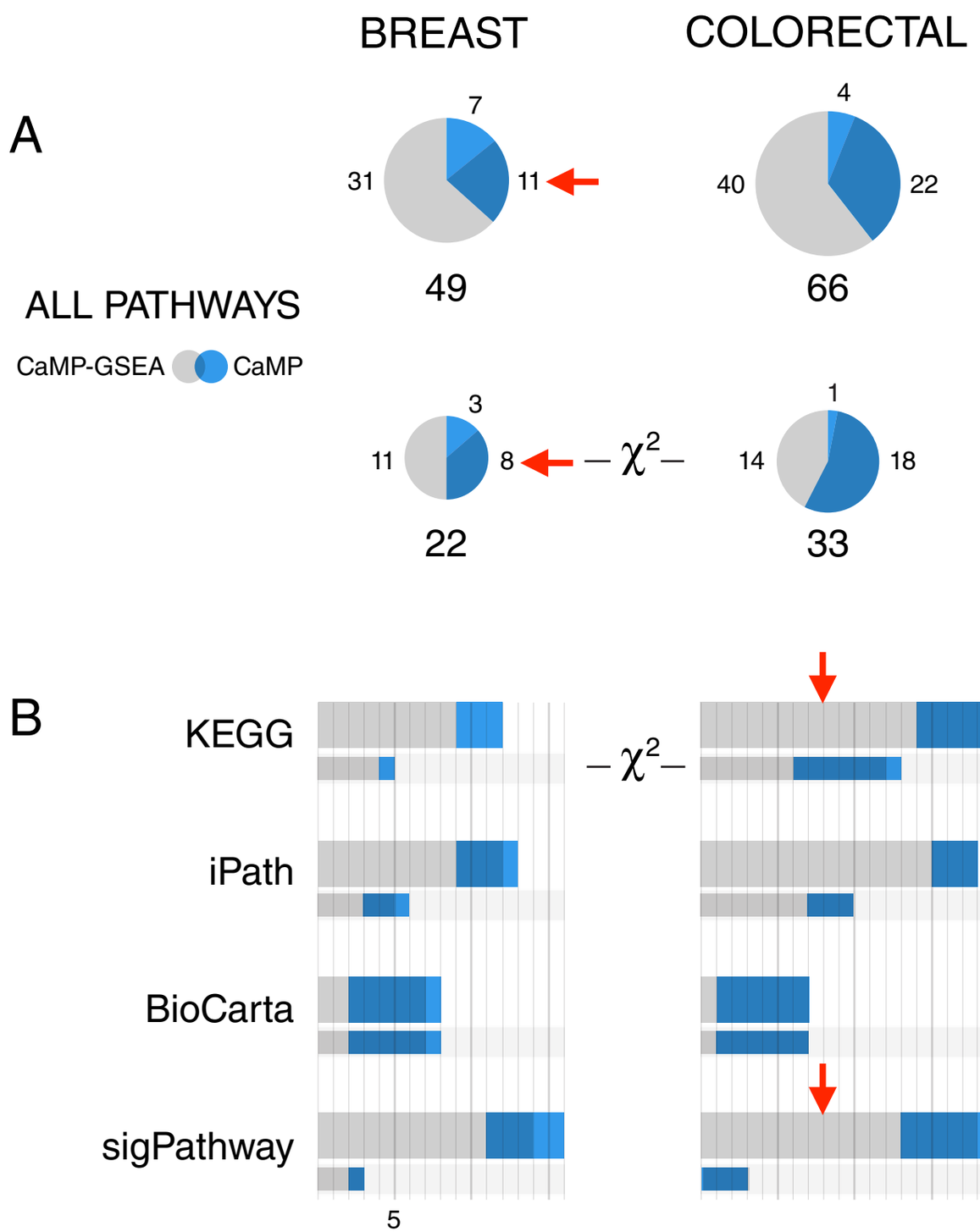
REFACTORING COMPLEXITY







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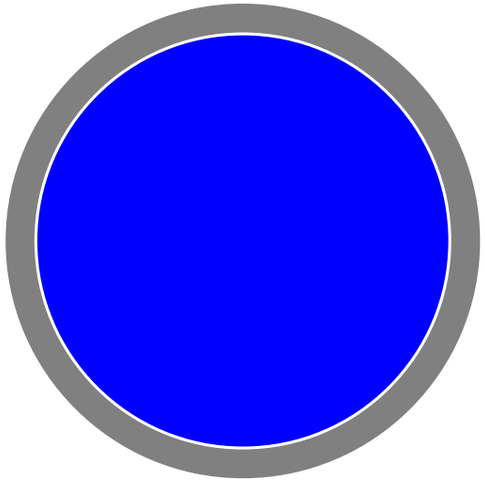
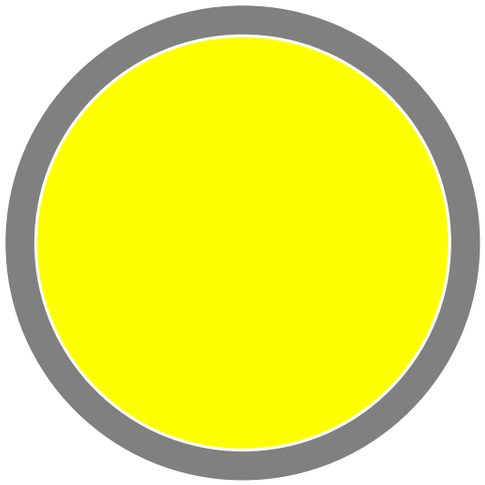
COLOR PERCEPTION





HSB COLOR SPACE

HUE	240	60
SATURATION	1	1
BRIGHTNESS	1	1

LCH COLOR SPACE

HUE	266	86
CHROMA	130	107
LIGHTNESS	0.32	0.97

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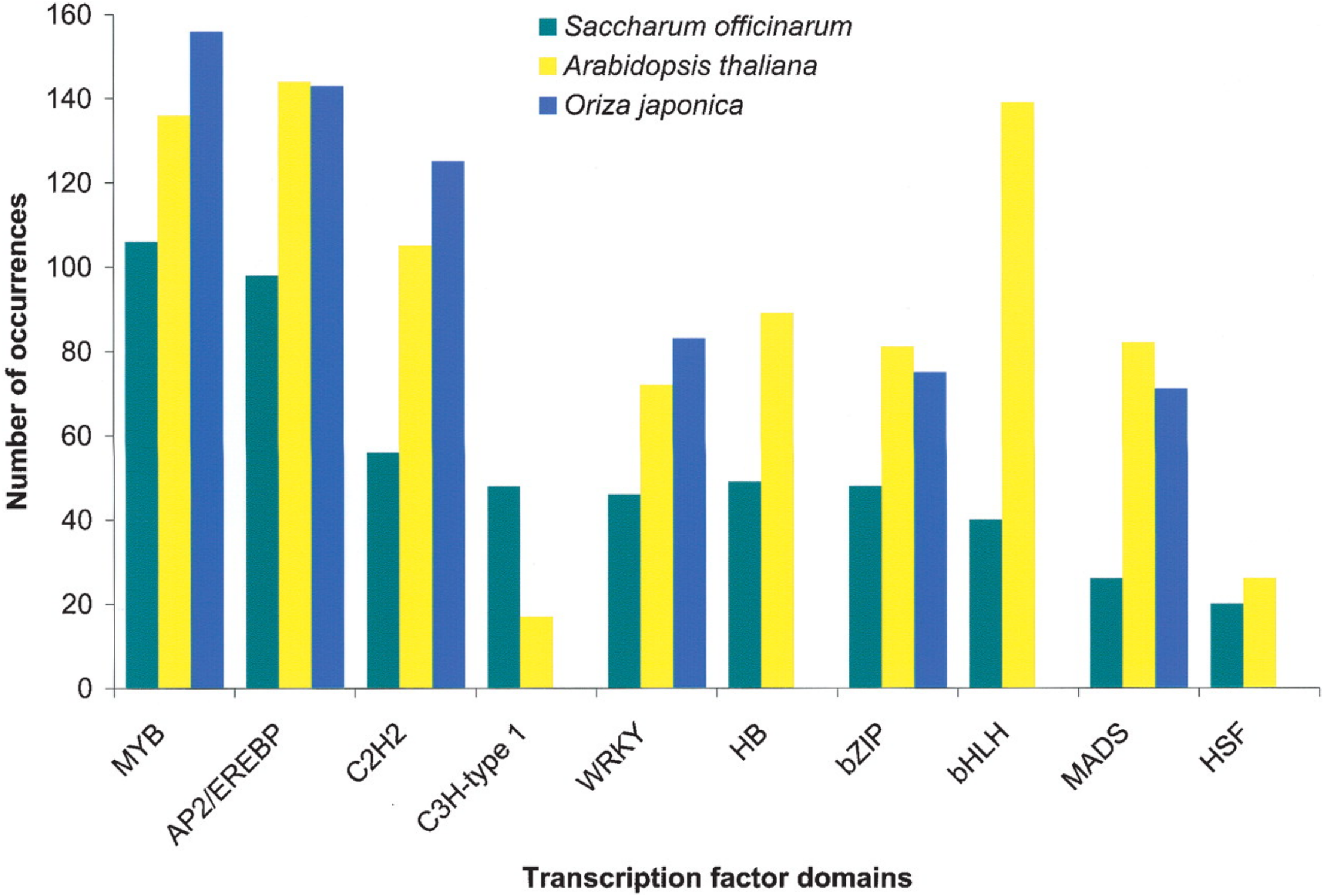
COLOR PERCEPTION



The 10 most common transcription factor Pfam domains in SAS proteins. Vettore, A.L., et al., Analysis and functional annotation of an expressed sequence tag collection for tropical crop sugarcane. Genome Res, 2003. 13(12): p. 2725-35.

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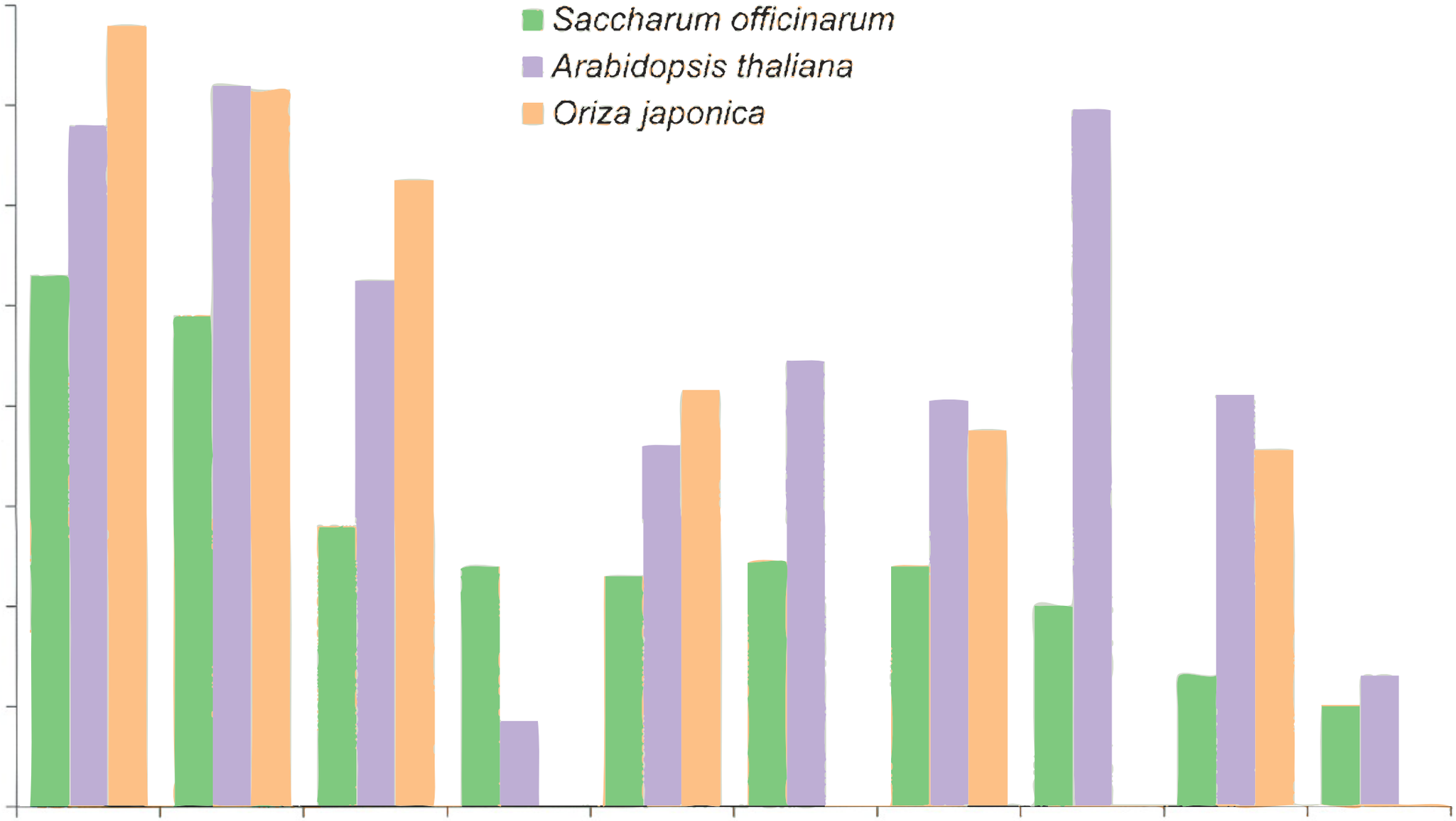
COLOR PERCEPTION



BREWER QUALITATIVE 3-COLOR PALETTES

ACCENT PASTEL 1 SET 2

WWW.COLORBREWER.ORG

In a qualitative palette, colors have no perceived order or importance.

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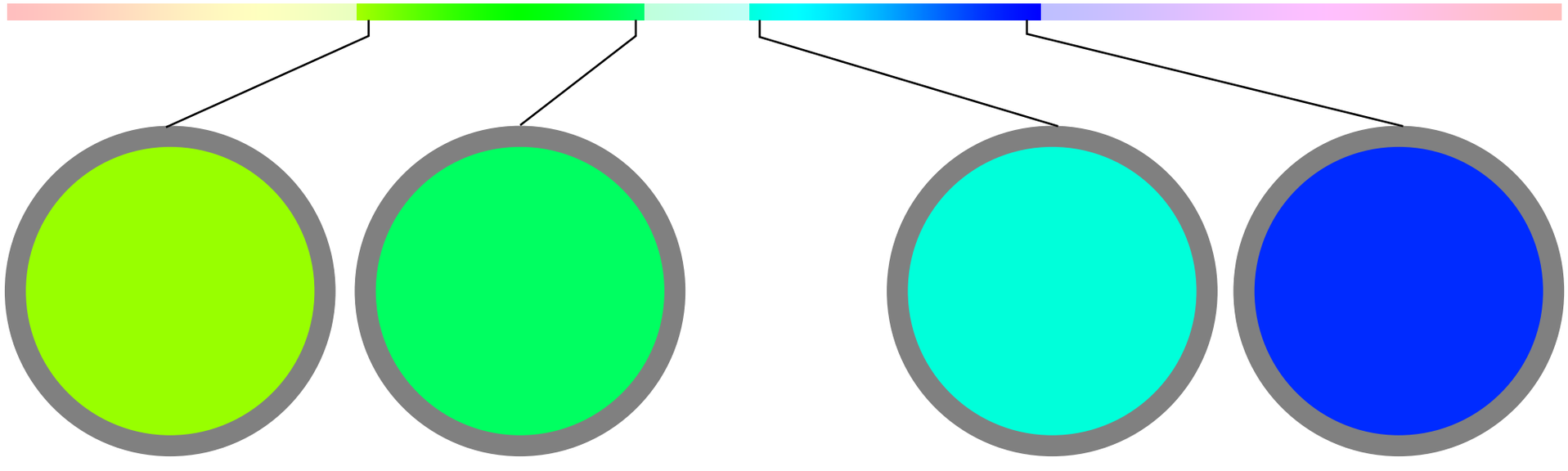
PERCEPTUAL UNIFORMITY



HSB COLOR SPACE		**ΔH = 60**		**ΔH = 60**
HUE	83	143	171	231
SATURATION	1	1	1	1
BRIGHTNESS	1	1	1	1

Lab COLOR SPACE		**ΔE_{ab} = 35**		**ΔE_{ab} = 176**
L	91	88	90	35
a	-59	-81	-58	70
b	87	60	4	-102

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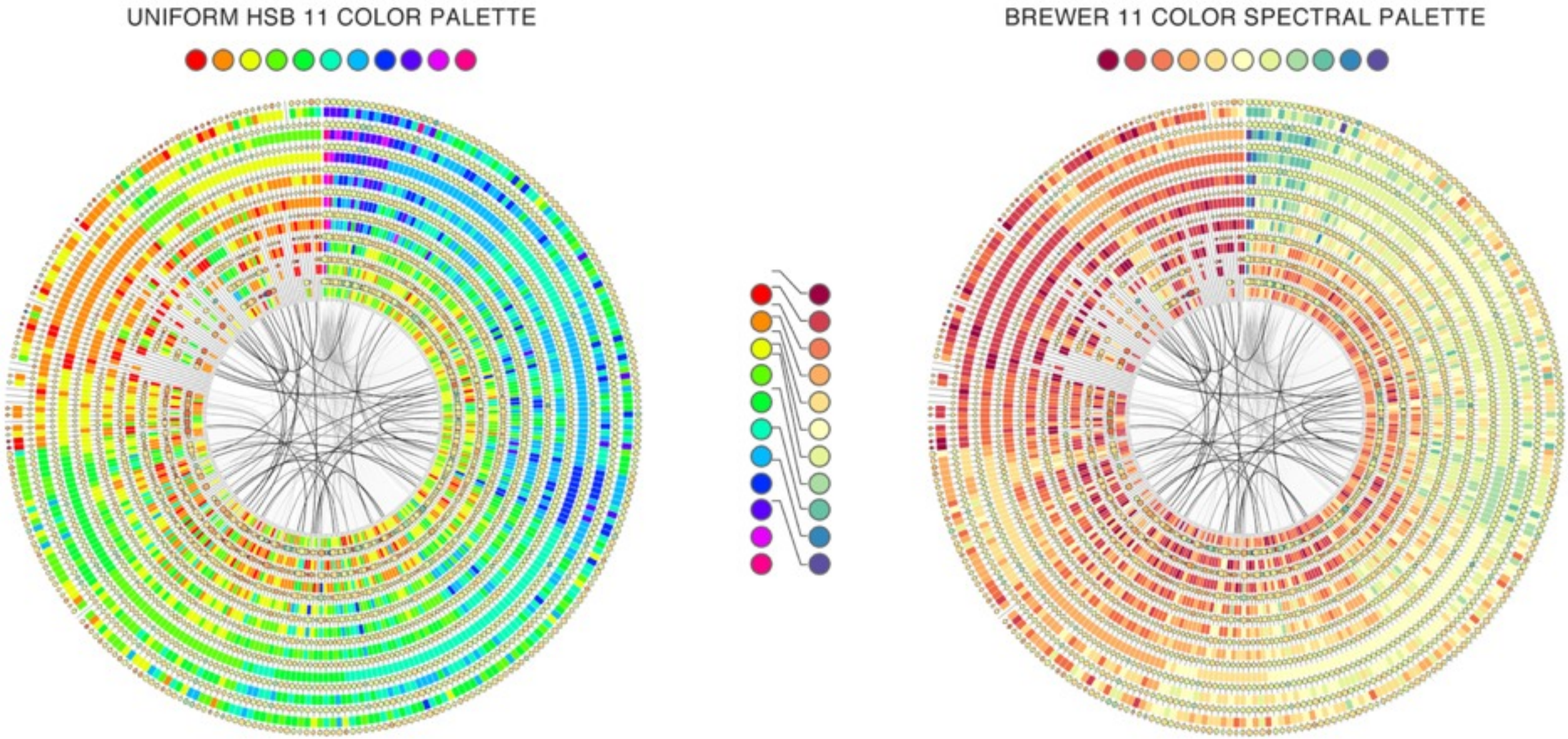
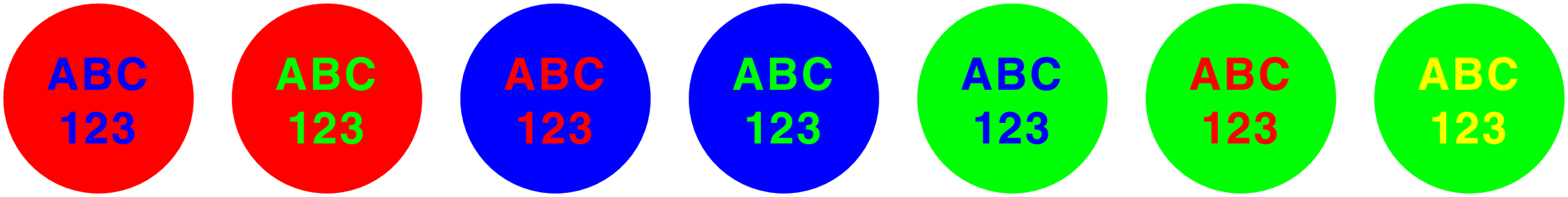
DIVERGING BREWER PALETTES



last.fm music listening habits by age.
http://mkweb.bcgsc.ca/spl/circos-lastfm-legend.png

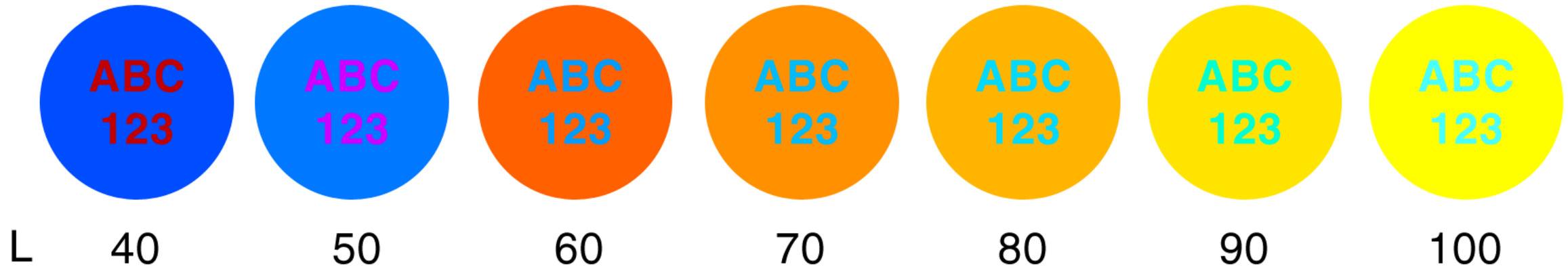
CONTRAST

AVOID ADJACENT PURE COLORS



AVOID ADJACENT COLORS WITH SIMILAR LUMINANCE

$\Delta L = 0$



Simultaneous contrast occurs when two pure colors are adjacent.
Poor contrast occurs when two colors have similar luminance (perceived brightness).

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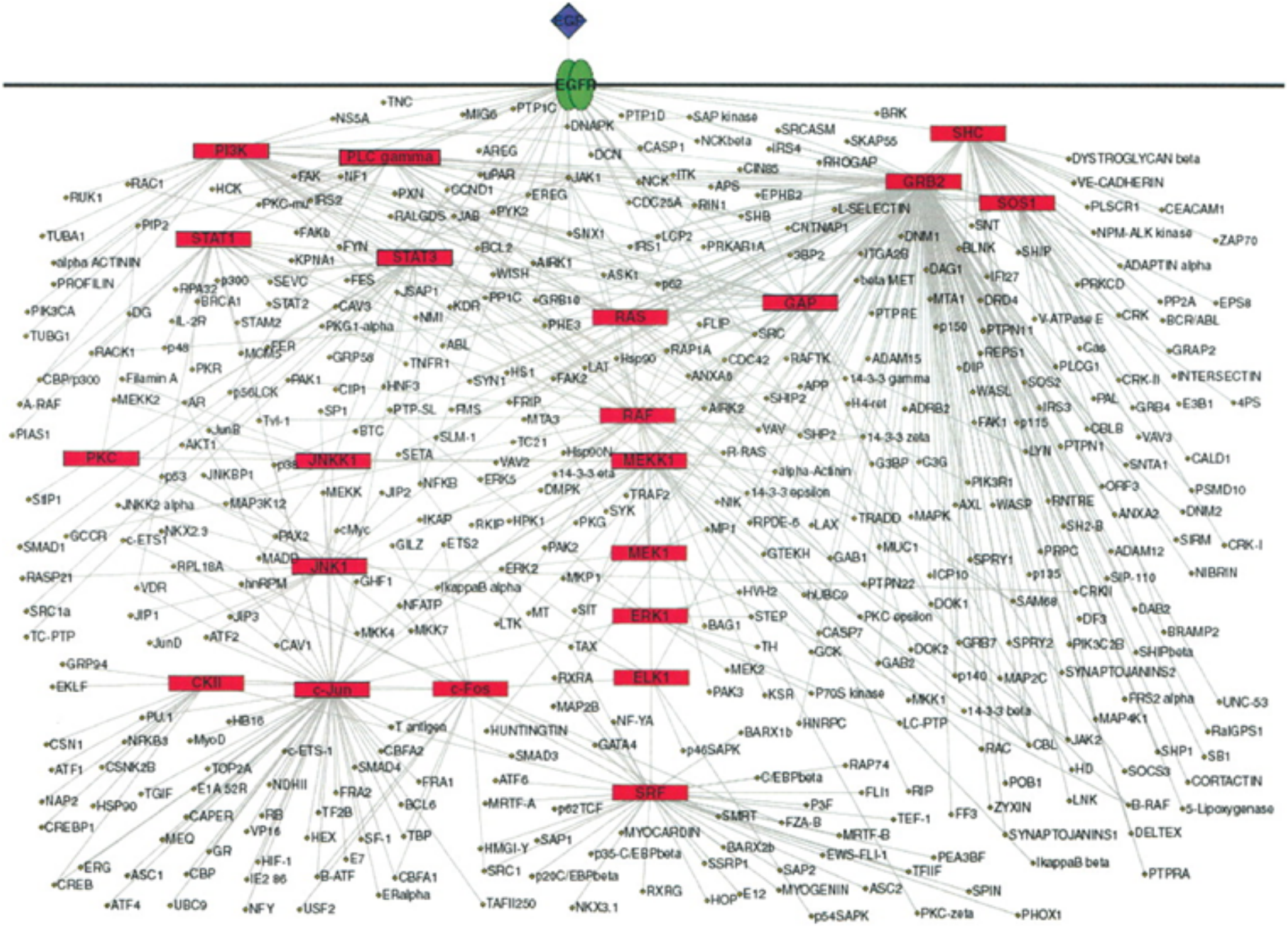
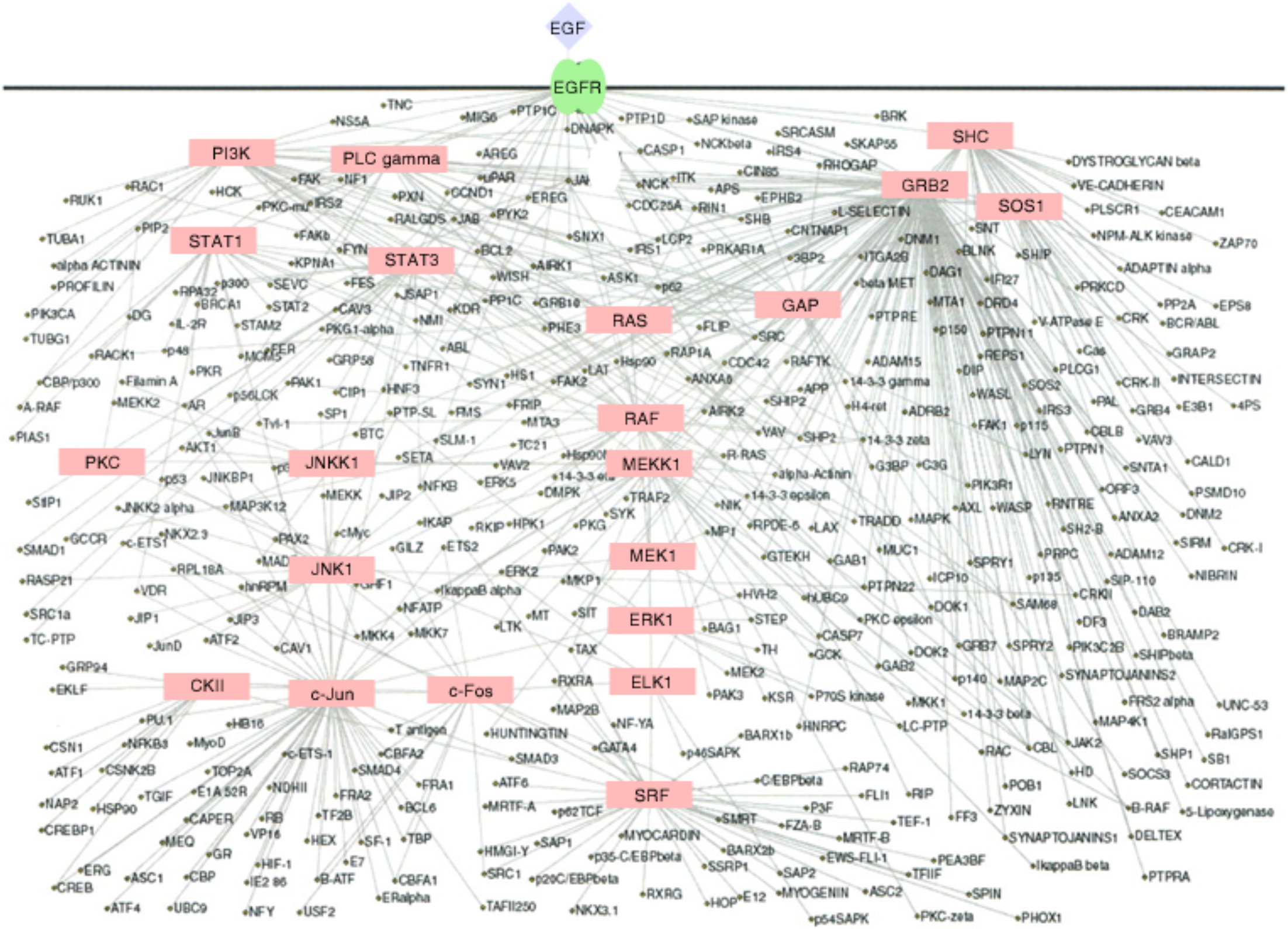
CONTRAST


EGF
EGFR
PI3K
PLC gamma
STAT1
STAT3
RAS
RAF
MEK1
ERK1
JNKK1
JNK1
MEKK1
PKC
CKII
c-Jun
c-Fos
ELK1
SRF
GAP
SHC
GRB2
SOS1
TNC
NS5A
MIG6
PTP1C
PTP1D
DNAPK
SAP kinase
SRCASM
BRK
SKAP55
NCKbeta
IRS4
RHOGAP
CASP1
DCN
AREG
uPAR
EREG
JAK1
NCK
ITK
CIN85
APS
EPHB2
CDC25A
RIN1
SHB
L-SELECTIN
CNTNAP1
DNM1
SNT
BLNK
SHIP
ITGA2B
3BP2
IRS1
LCP2
PRKAR1A
SNX1
BCL2
AIRK1
WISH
ASK1
p62
PP1C
GRB10
KDR
NMI
PHE3
FLIP
SRC
RAP1A
Hsp90
CDC42
RAFTK
ANXA6
APP
SHIP2
AIRK2
VAV
SHP2
R-RAS
MTA3
FRIP
SYN1
HS1
LAT
FAK2
TNFR1
ABL
GRP58
PKG1-alpha
STAM2
BRCA1
STAT2
CAV3
JSAP1
FES
SEVC
p300
RPA32
KPNA1
FAKb
FYN
PKC-mu
IRS2
RALGDS
JAB
PYK2
PXN
CCND1
FAK
NF1
HCK
RAC1
RUK1
PIP2
TUBA1
alpha ACTININ
PROFILIN
PIK3CA
DG
TUBG1
RACK1
p48
CBP/p300
Filamin A
A-RAF
MEKK2
PKR
AR
p56LCK
PAK1
CIP1
HNF3
SP1
PTP-SL
RMS
SLM-1
TC21
Hsp90N
VAV2
ERK5
DMPK
TRAF2
SYK
NIK
RPDE-6
LAX
TRADD
MAPK
MP1
PAK2
MKP1
ERK2
IkappaB alpha
NFATP
MT
SIT
LTK
MKK4
MKK7
TAX
RXRA
MAP2B
NF-YA
HUNTINGTIN
GATA4
SMAD3
p46SAPK
ATF6
MRTF-A
p62TCF
SAP1
HMGI-Y
SRC1
p20C/EBPbeta
TAFII250
NKX3.1
RXRG
HOP
E12
MYOCARDIN
p35-C/EBPbeta
BARX2b
SSRP1
SAP2
MYOGENIN
ASC2
SPIN
p54SAPK
PKC-zeta
PHOX1
TFIIF
PEA3BF
EWS-FLI-1
MRTF-B
SMRT
FZA-B
P3F
TEF-1
FF3
C/EBPbeta
RAP74
FLI1
RIP
POB1
ZYXIN
LNK
B-RAF
5-Lipoxygenase
SYNAPTOJANINS1
DELTEX
HD
SOCS3
CORTACTIN
RAC
CBL
JAK2
SHP1
SB1
RalGPS1
MAP4K1
FRS2 alpha
UNC-53
MKK1
14-3-3 beta
LC-PTP
HNRPC
BARX1b
PAK3
KSR
P70S kinase
p140
MAP2C
SYNAPTOJANINS2
DF3
GAB2
DOK2
GRB7
SPRY2
PIK3C2B
SHIPbeta
BRAMP2
DAB2
PKC epsilon
CASP7
TH
GCK
STEP
BAG1
HVH2
hUBC9
PTPN22
ICP10
DOK1
SAM68
CRKII
SIP-110
p135
SPRY1
PRPC
ADAM12
NIBRIN
SIRM
CRK-I
GTEKH
GAB1
MUC1
PAK1
IRS3
p115
PAL
GRB4
E3B1
4PS
CRK-II
INTERSECTIN
SOS2
WASL
PLCG1
DIP
REPS1
Cdc
GRAP2
V-ATPase E
CRK
PP2A
EPS8
BCR/ABL
PTPN11
p150
MTA1
DRD4
PTPRE
ADAM15
14-3-3 gamma
H4-rot
ADRB2
DAG1
IFI27
beta MET
PRKCD
ADAPTIN alpha
NPM-ALK kinase
ZAP70
PLSCR1
CEACAM1
VE-CADHERIN
DYSTROGLYCAN beta
SINA1
CALD1
PSMD10
DNM2
ANXA2
SH2-B
ORF3
RNTRE
PTPN1
LYN
VAV3
CBLB
PIK3R1
AXL
WASP
14-3-3 zeta
G3BP
C3G
alpha-Actinin
14-3-3 epsilon
14-3-3 eta
TIAM1
RAC1
HCK

GOOD CONTRAST



Decreasing the saturation of the background colors improves contrast.

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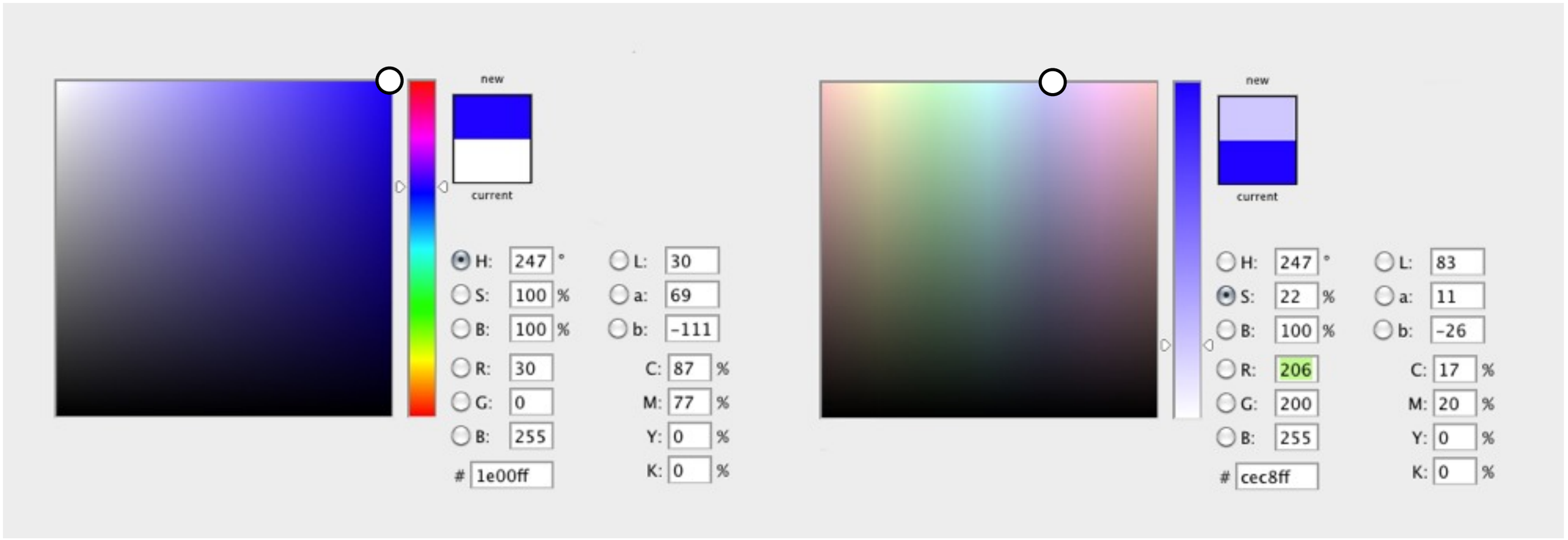
USING COLOR PICKERS



Photoshop shows a color's coordinates in several color spaces. Decrease saturation to make a color appear lighter. Use the "L" channel of the Lab space to determine a color's perceived brightness (luminance).

legibility**clarity**attractiveness

STRONG MESSAGE
REDUNDANCY
EXCESS INK
GLYPHS
OUTLIER HIJACK

IMPORTANCE OF CLARITY

This is fairly clear. Either

(a) do not poop near the tiny trees, or

(b) no pooping for giants

This is less clear. Perhaps

(a) no talking

(b) did you remember your black glove?

(c) stop and wait

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IS YOUR MESSAGE NECESSARY?

http://lushlush.livejournal.com/190093.html

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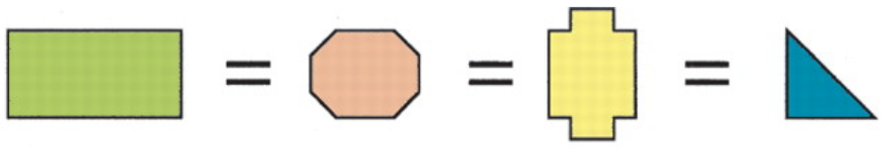
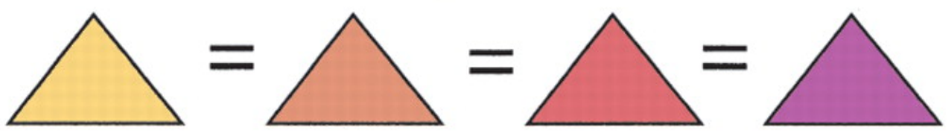
ACADEMIC FIGURE OR MENSA TEST?

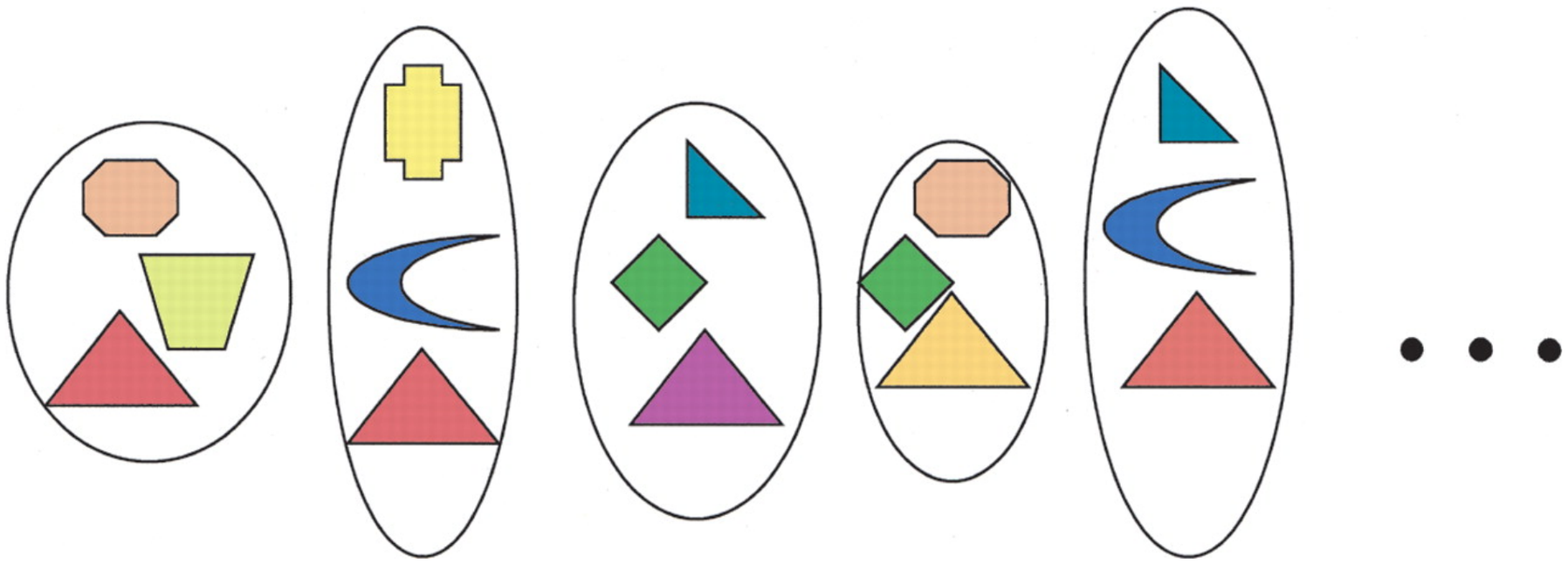


ENVELOPE

METABOLISM



TRANSLATION



A mix-and-match model for prokaryotic genome evolution. Charlebois, R.L. and W.F. Doolittle, Computing prokaryotic gene ubiquity: rescuing the core from extinction. Genome Res, 2004. 14(12): p. 2469-77.

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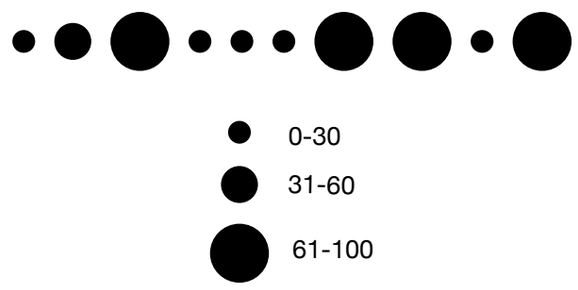
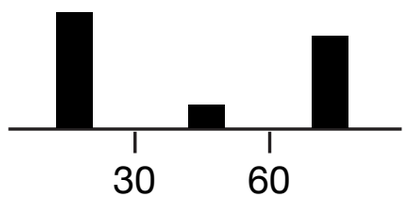
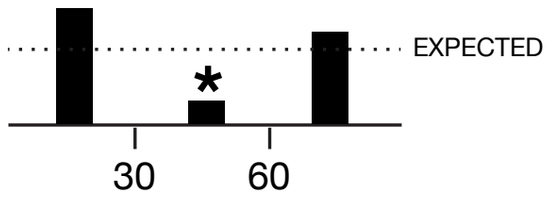
CRAFTING A MESSAGE

WHAT IS SHOWN?		WHAT IS COMMUNICATED?	WHAT IS INTERPRETED?
RAW DATA	12 54 82 29 25 22 67 61 23 79	NO CLEAR MESSAGE.	UNKNOWN. READER IS ON THEIR OWN.
DISCRETIZED		SCALE	THREE RANGES ARE IMPORTANT. INDIVIDUAL VALUES WITHIN A RANGE ARE NOT.
BINNED		DISTRIBUTION	THERE ARE FEWER MEDIUM-SIZED VALUES.
TREND		SIGNIFICANCE	THERE ARE SIGNIFICANTLY FEWER MEDIUM-SIZED VALUES.

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CRAFTING A MESSAGE

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DISCRETIZED		SCALE	THREE RANGES ARE IMPORTANT. INDIVIDUAL VALUES WITHIN A RANGE ARE NOT.
BINNED		DISTRIBUTION	THERE ARE FEWER MEDIUM-SIZED VALUES.
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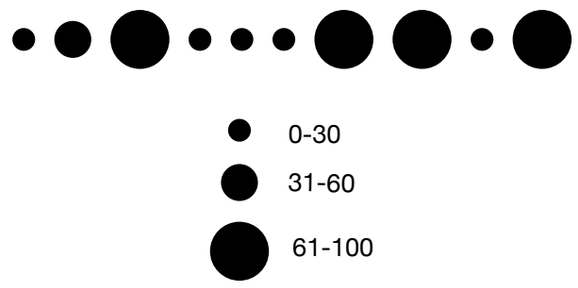
DISCRETIZED		SCALE	THREE RANGES ARE IMPORTANT. INDIVIDUAL VALUES WITHIN A RANGE ARE NOT.
BINNED		DISTRIBUTION	THERE ARE FEWER MEDIUM-SIZED VALUES.
TREND		SIGNIFICANCE	THERE ARE SIGNIFICANTLY FEWER MEDIUM-SIZED VALUES.

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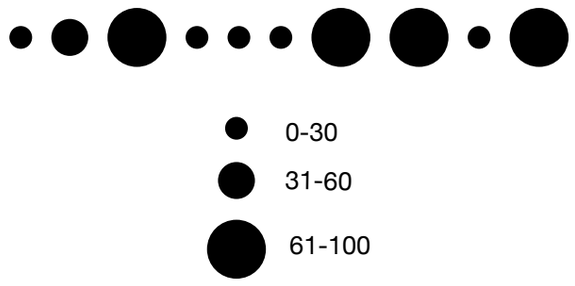
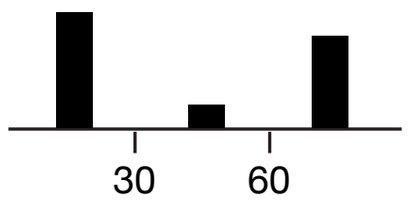
DISCRETIZED		SCALE	THREE RANGES ARE IMPORTANT. INDIVIDUAL VALUES WITHIN A RANGE ARE NOT.
BINNED		DISTRIBUTION	THERE ARE FEWER MEDIUM-SIZED VALUES.
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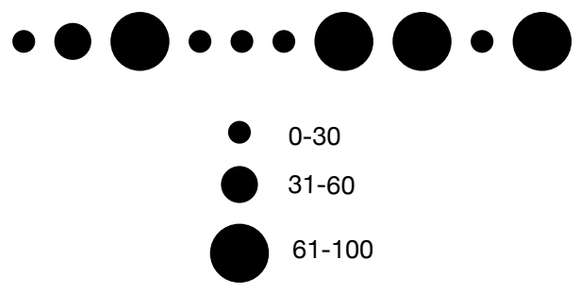
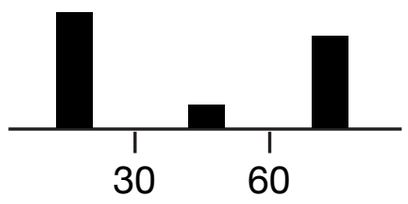
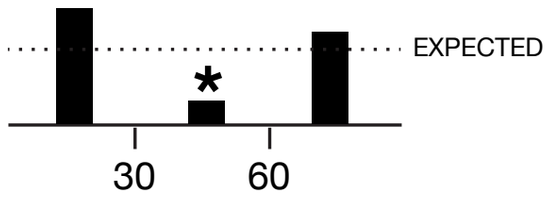
DISCRETIZED		SCALE	THREE RANGES ARE IMPORTANT. INDIVIDUAL VALUES WITHIN A RANGE ARE NOT.
BINNED		DISTRIBUTION	THERE ARE FEWER MEDIUM-SIZED VALUES.
TREND		SIGNIFICANCE	THERE ARE SIGNIFICANTLY FEWER MEDIUM-SIZED VALUES.

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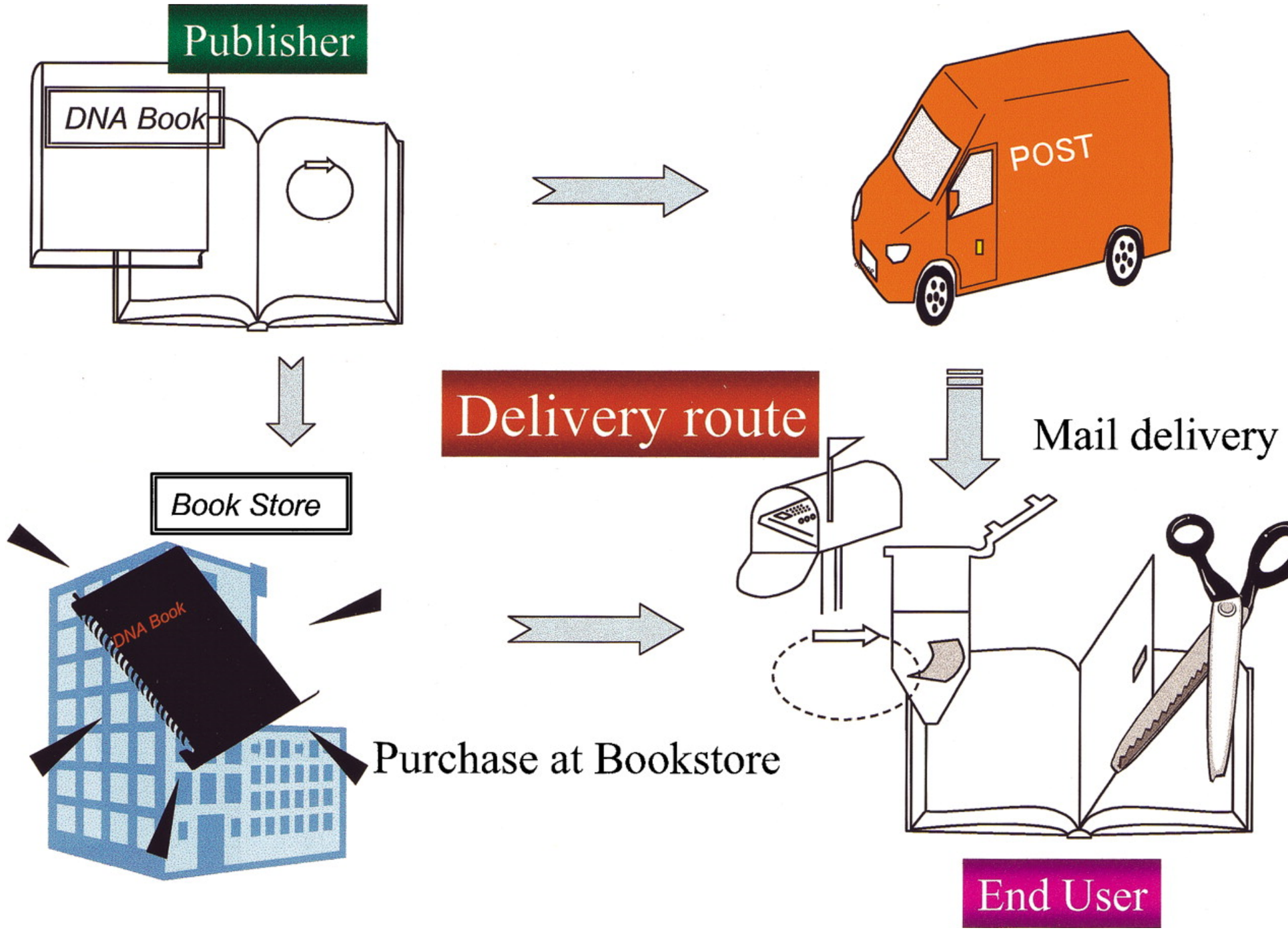
WHAT IS THE CORE MESSAGE?



Concept of the “DNA Book.” Kawai, J. and Y. Hayashizaki, DNA book. Genome Res, 2003. 13(6B): p. 1488-95.

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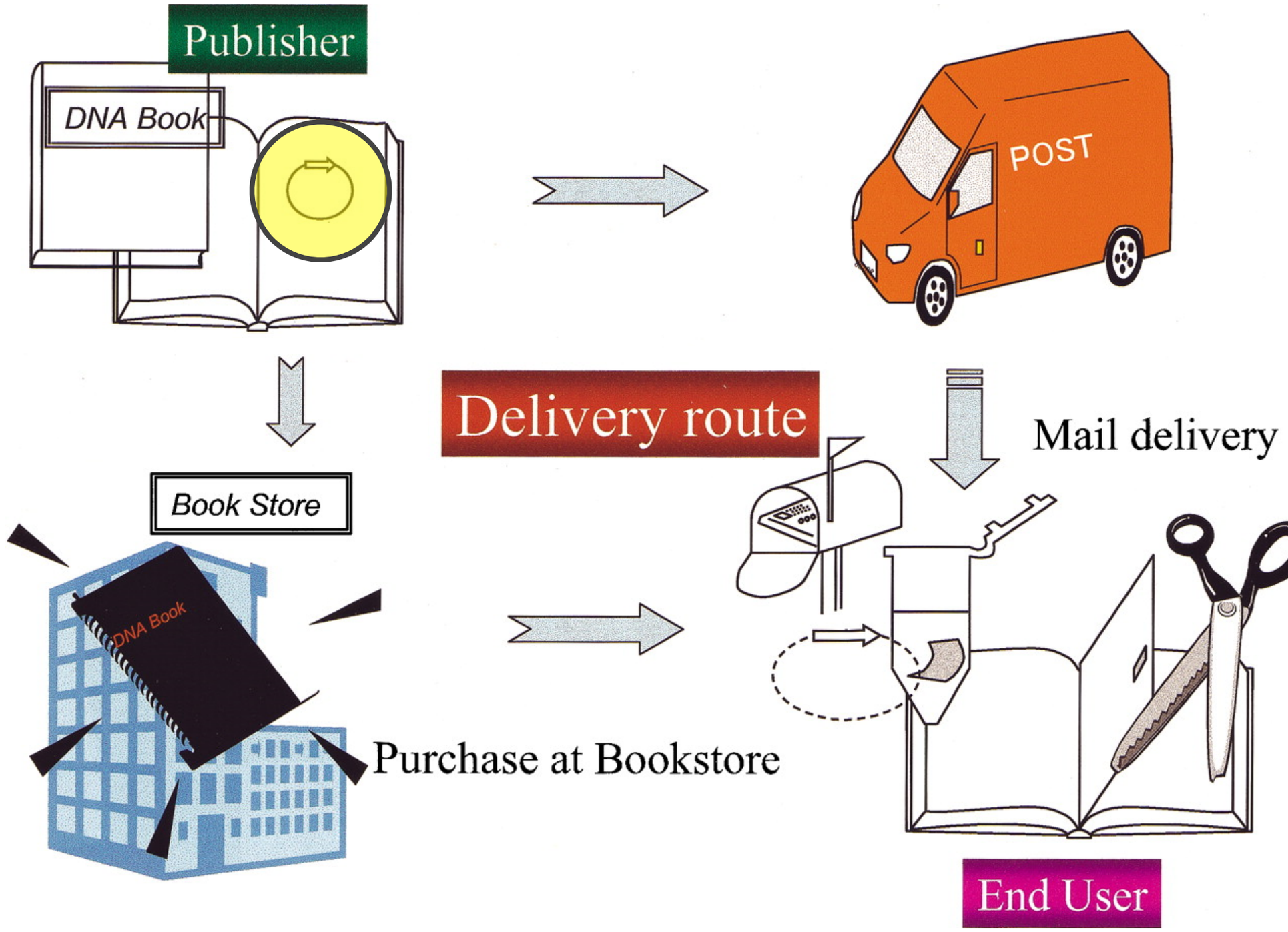

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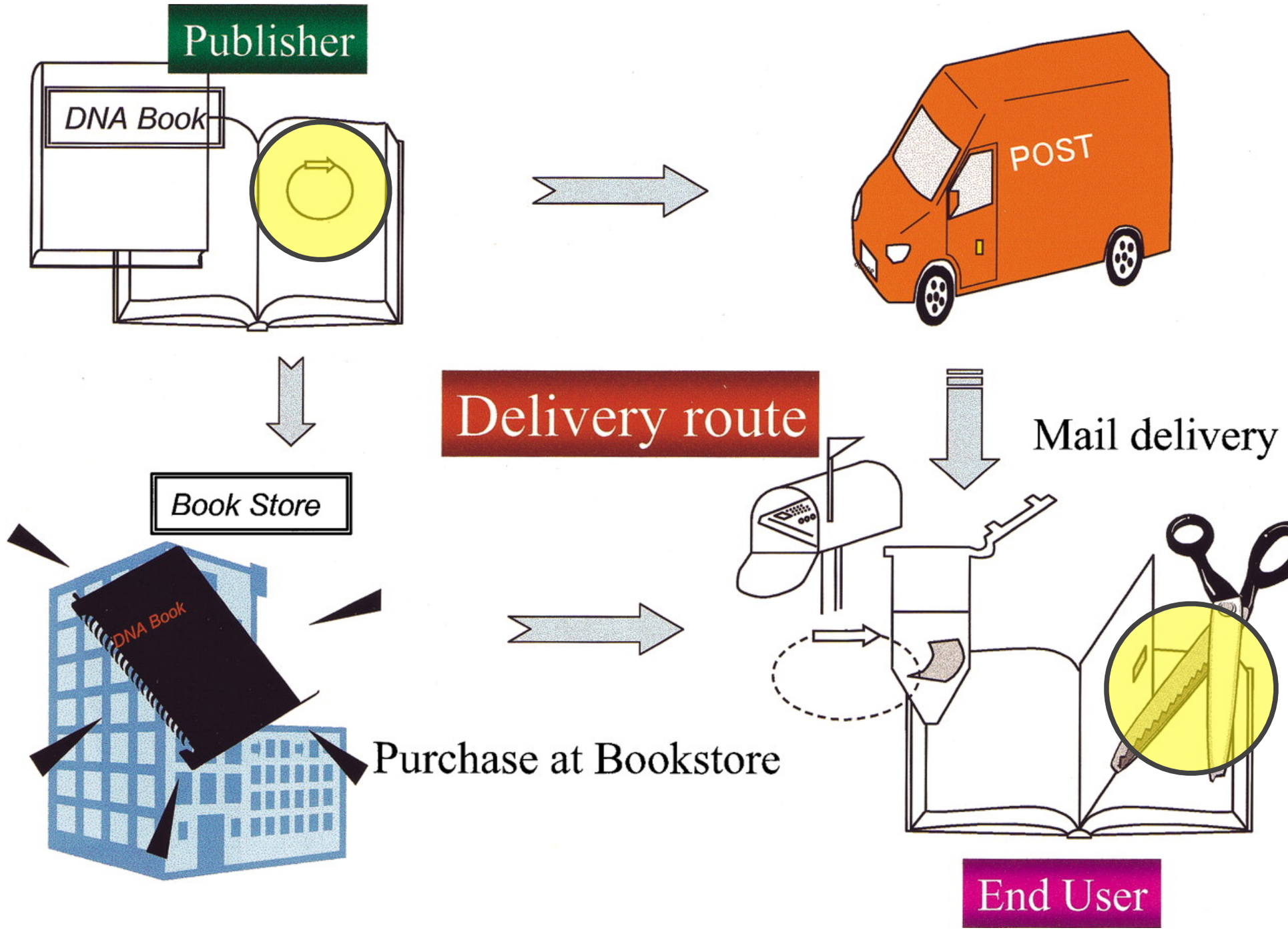

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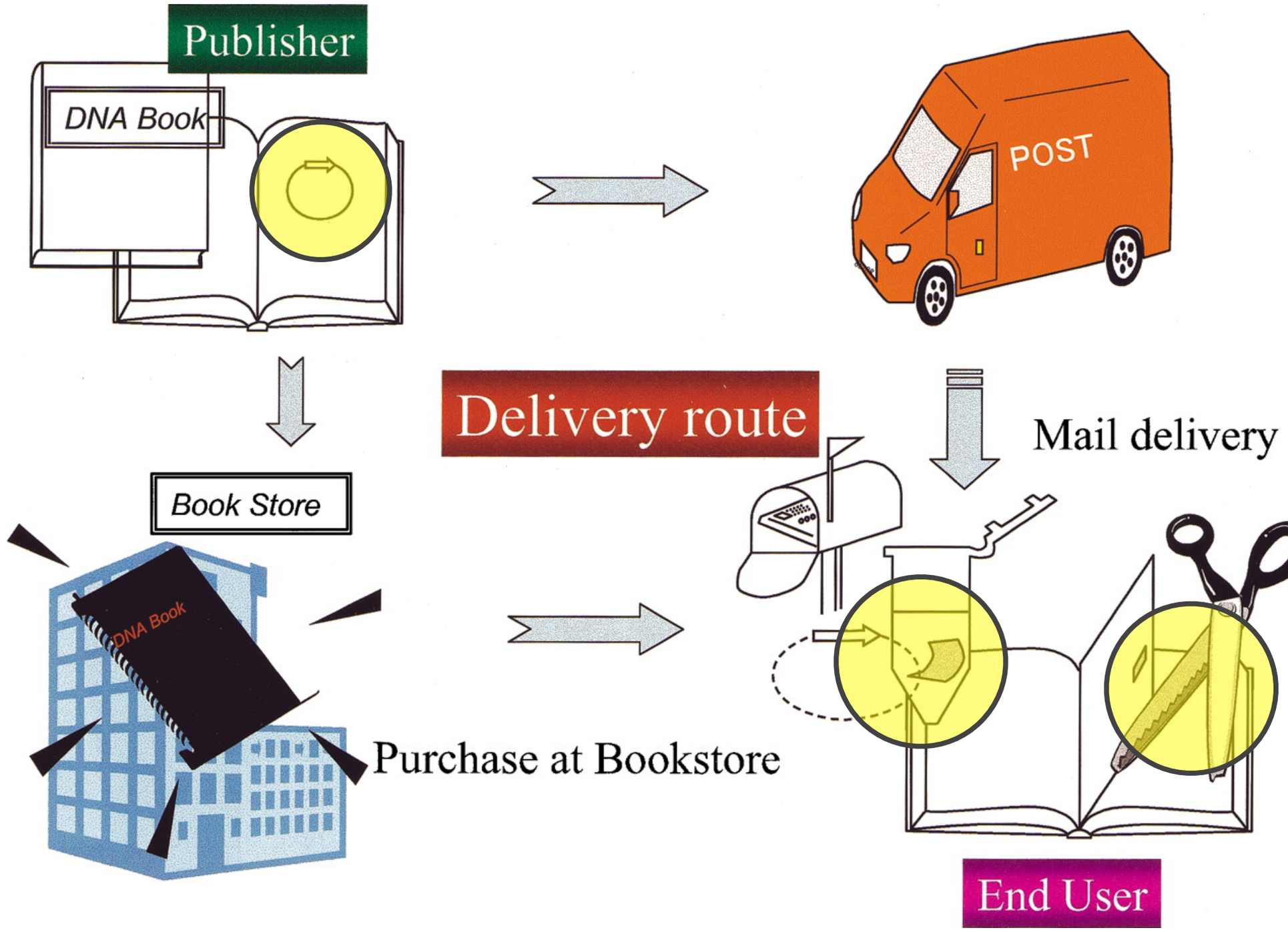

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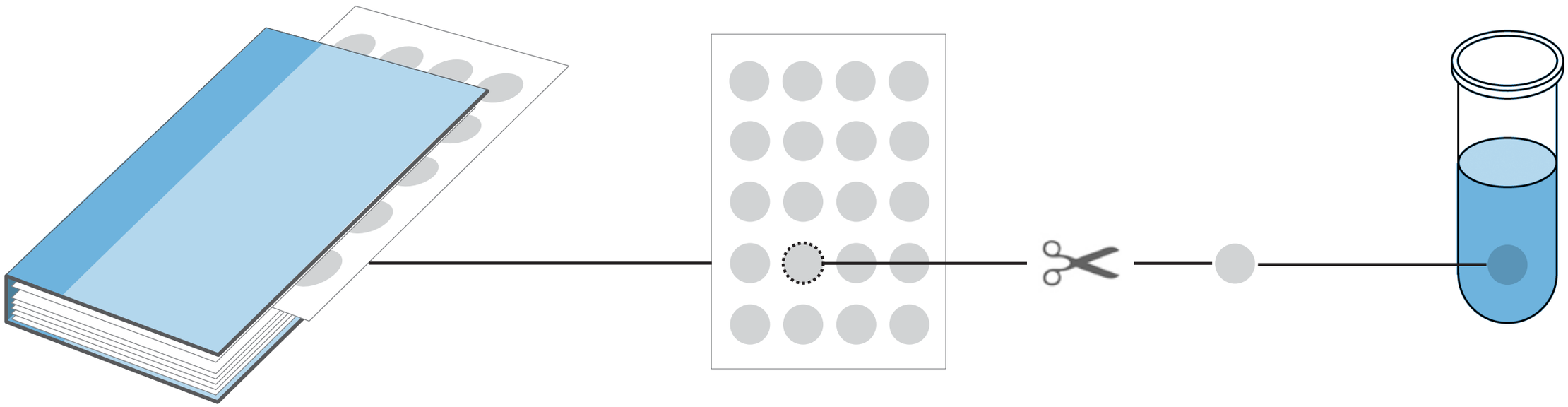
EXTRACTING THE CORE MESSAGE



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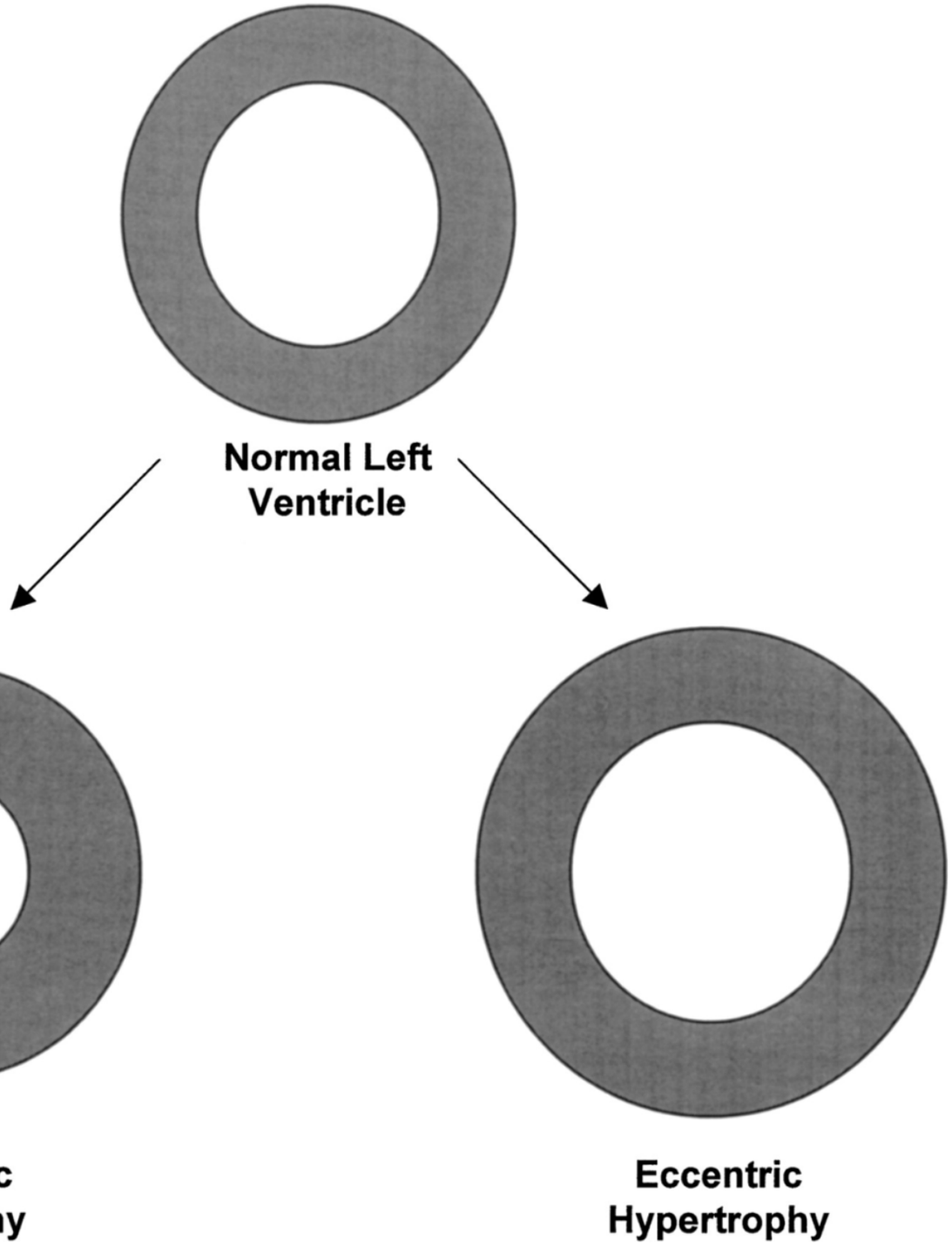
AMBIGUOUS PROPORTIONS



Nadeau, J.H., et al., Pleiotropy, homeostasis, and functional networks based on assays of cardiovascular traits in genetically randomized populations. Genome Res, 2003. 13(9): p. 2082-91.

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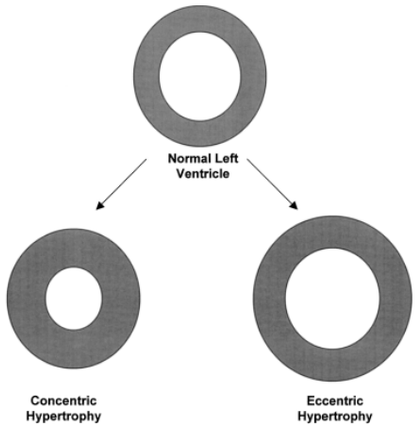
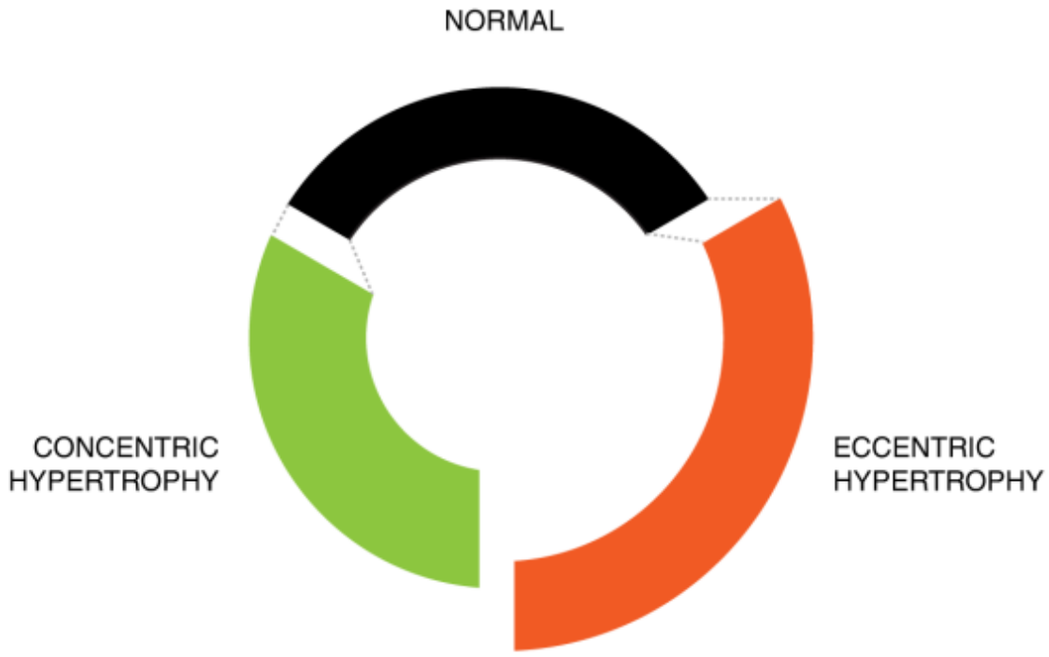
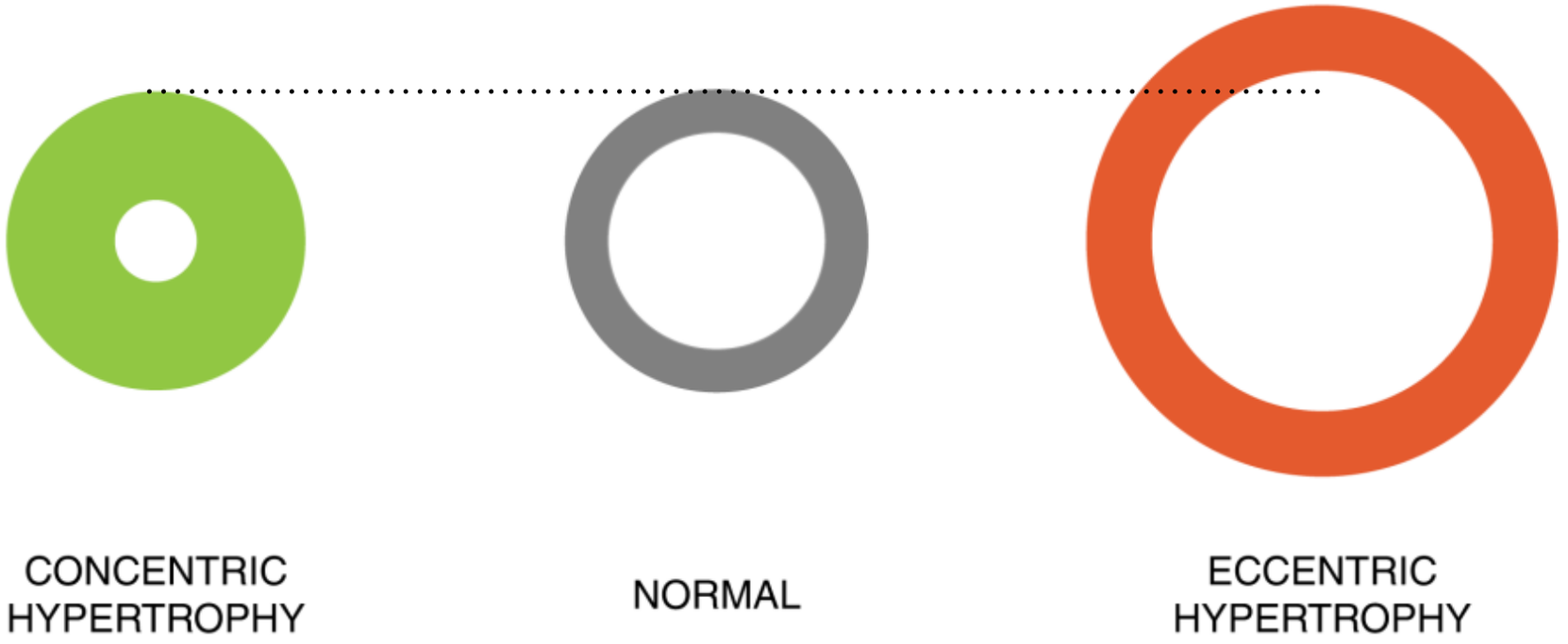
CLEAR PROPORTIONS







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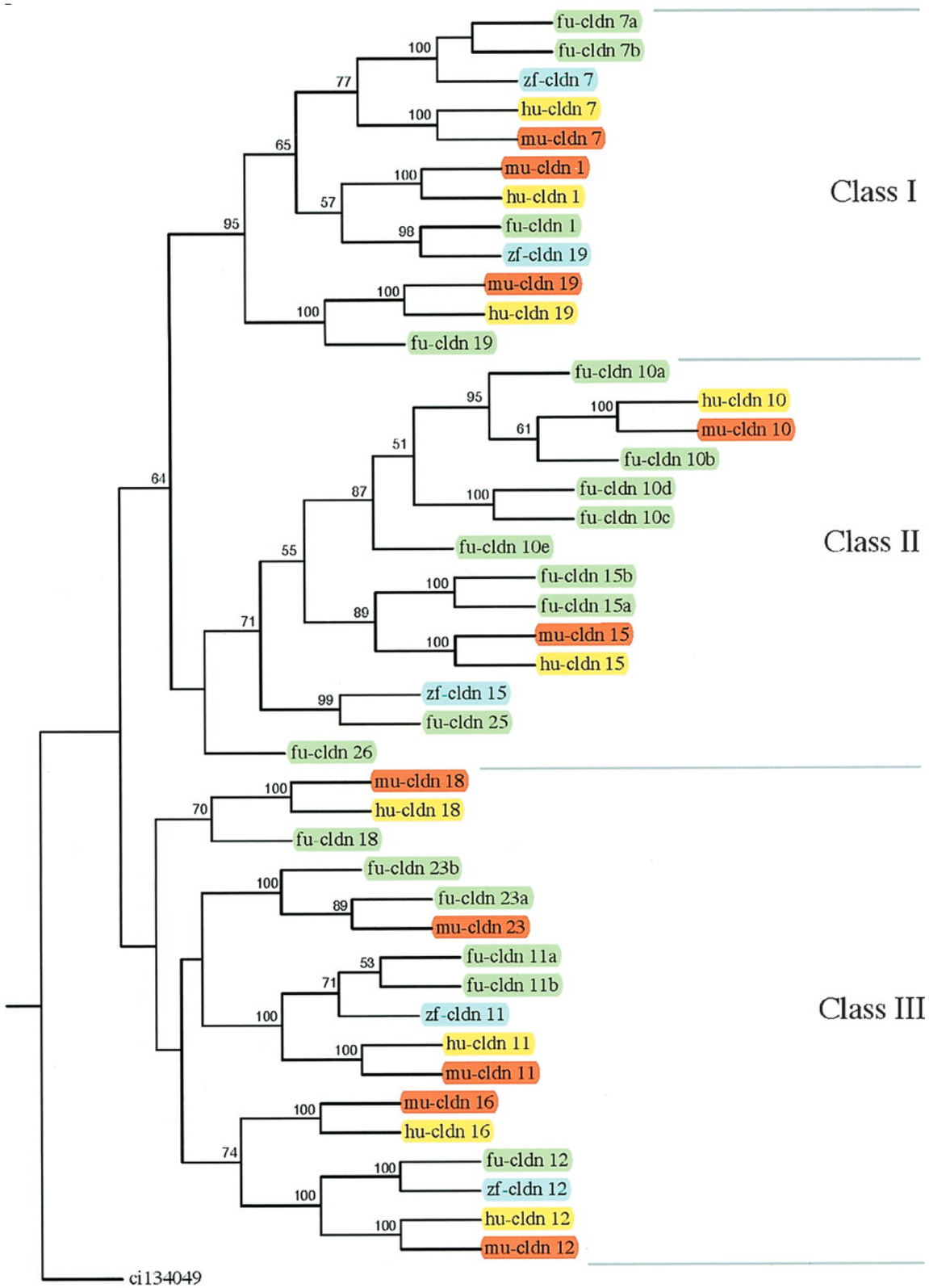
REDUNDANCY



All labels are of the form

```
fu-cldn 7a
fu-cldn 7b
zf-cldn 7
mu-cldn 19
hu-cldn 15
...
```

Instead, consider

```
F7a
F7b
Z7
M19
H15
...
```

Y. H. Loh, A. Christoffels, S. Brenner, W. Hunziker, B. Venkatesh, Genome Res 14, 1248 (Jul, 2004).

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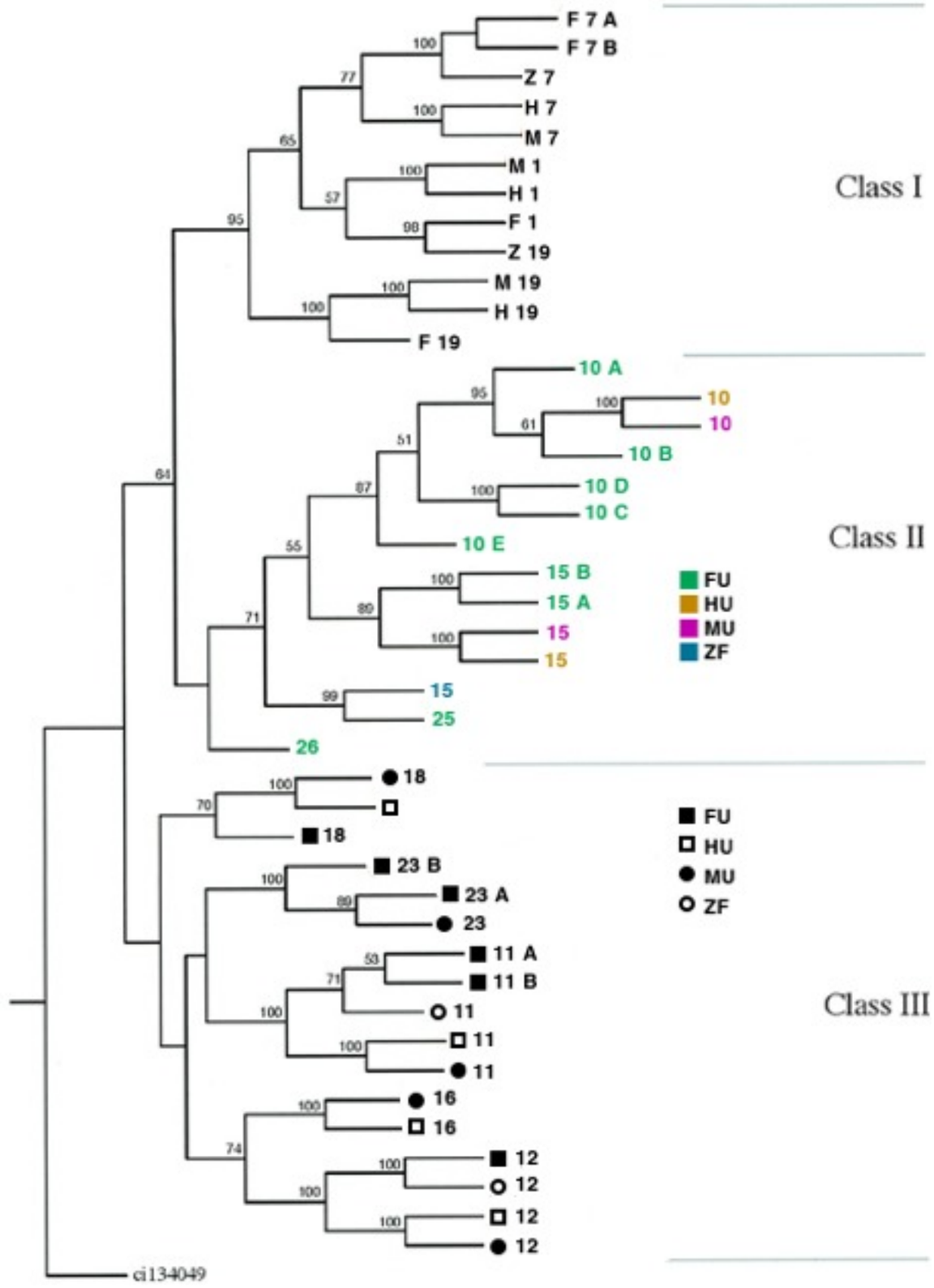
REFACTORED REDUNDANCY



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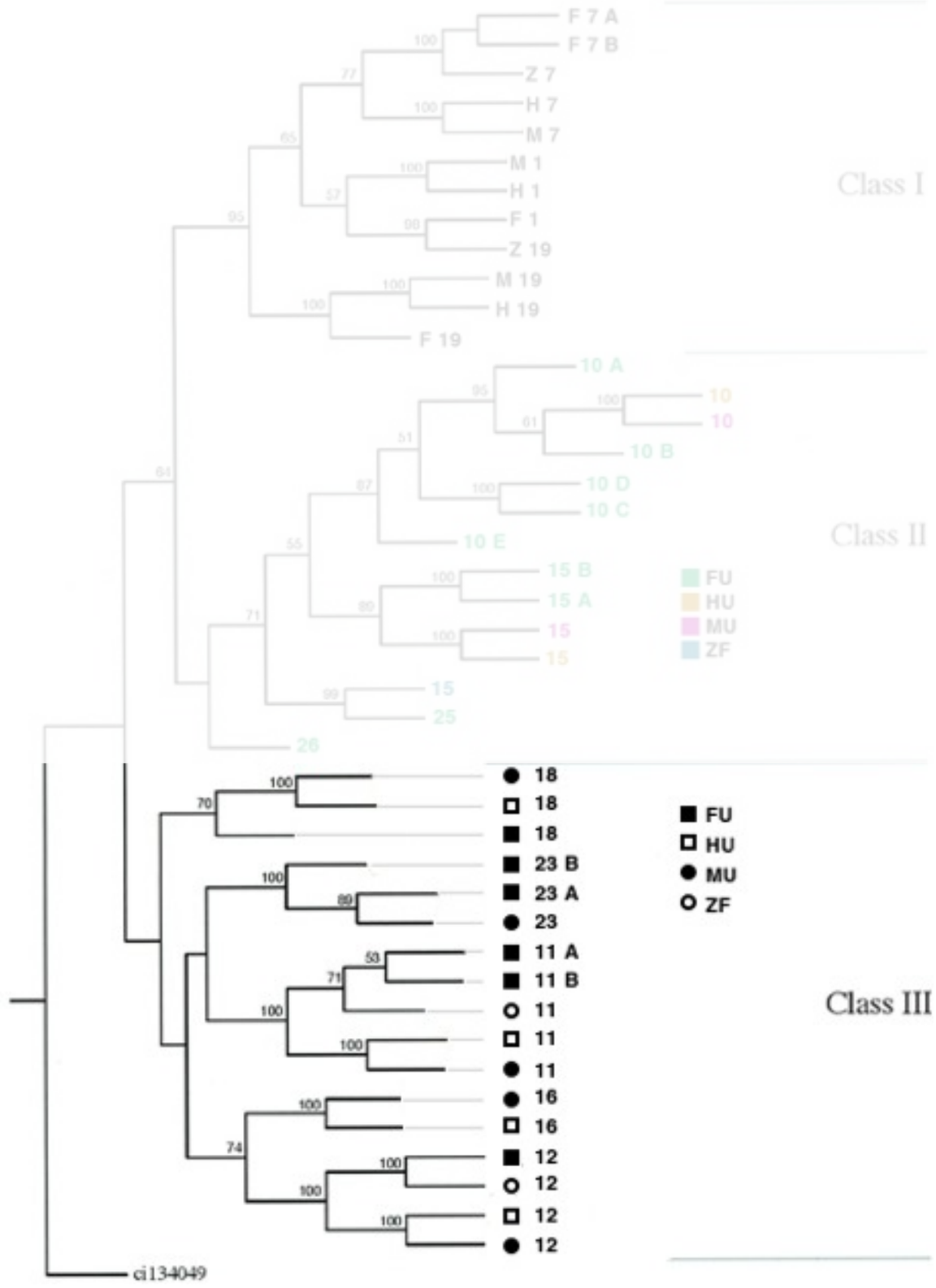
REFACTORED REDUNDANCY



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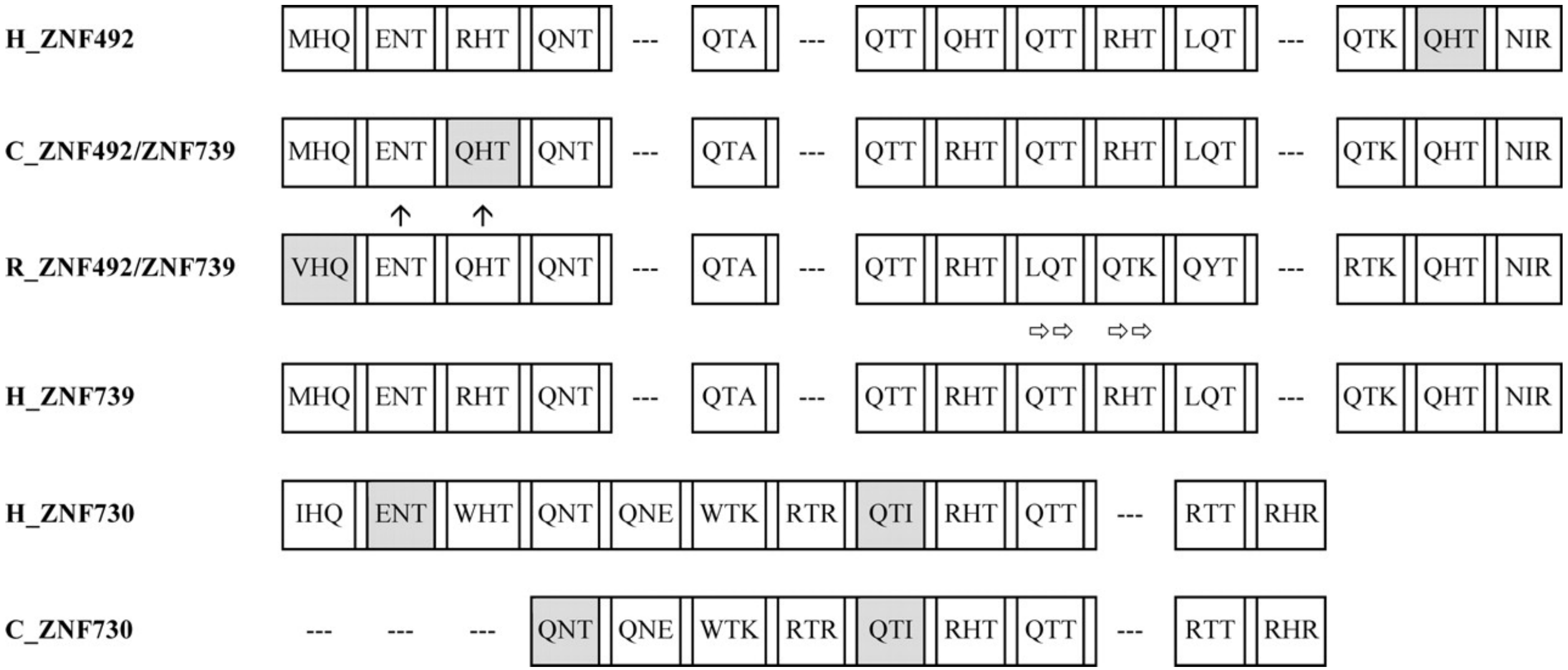
EXCESS INK



Zinc finger exon analysis for ZNF493 and ZNF738, two divergent genes from the ZNF431 clade. Hamilton, A.T., et al., Evolutionary expansion and divergence in the ZNF91 subfamily of primate-specific zinc finger genes. Genome Res, 2006. 16(5): p. 584-94.

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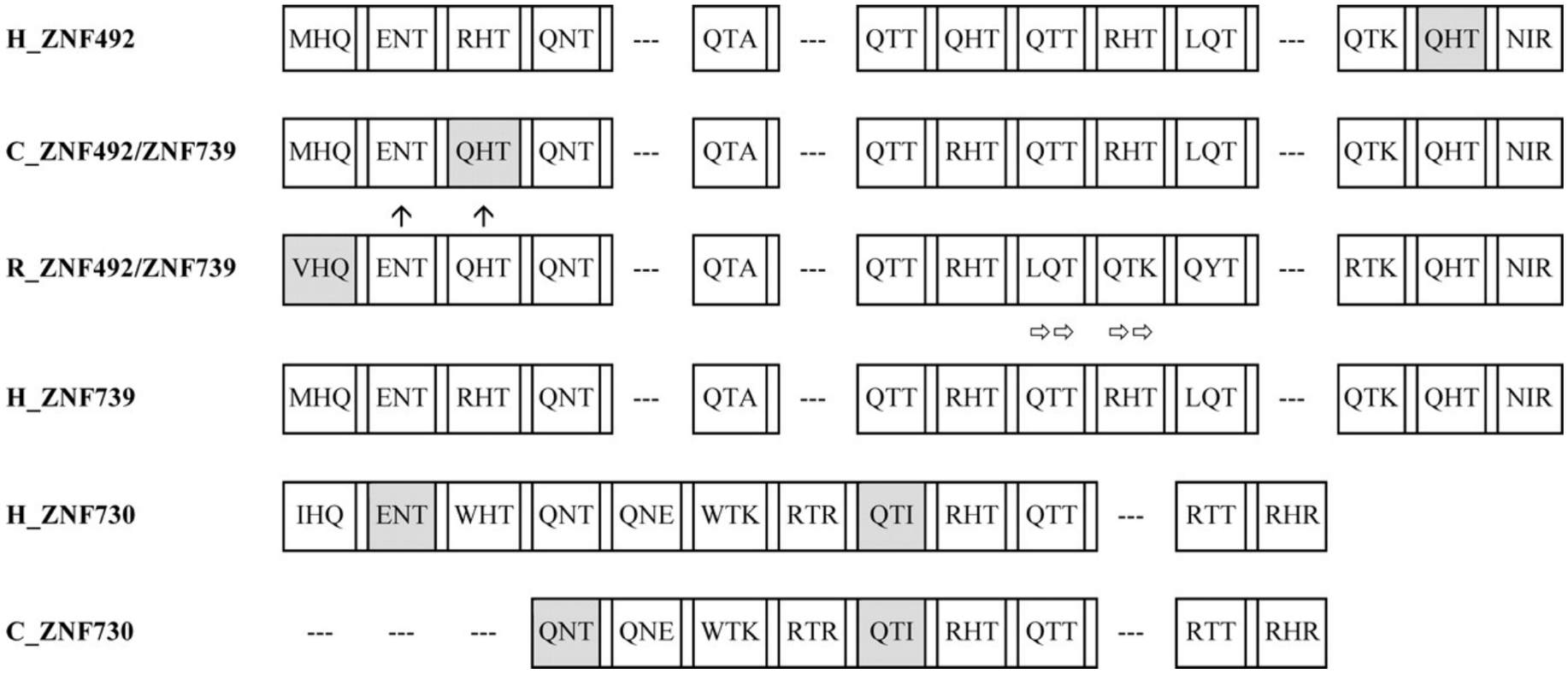

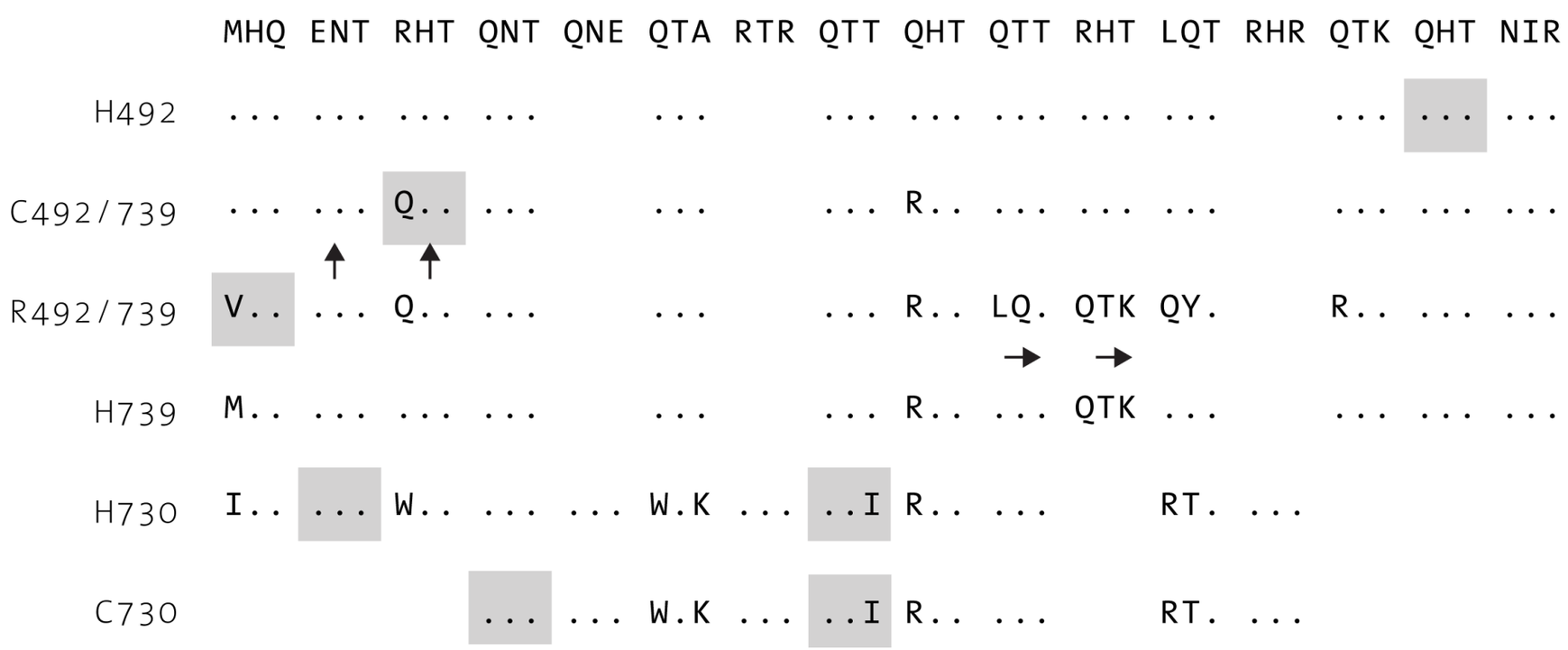

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THE LEGEND IS THE MAP

- all genes
- ▲ specific in situ result
- △ selective in situ result
- ▽ nonselective in situ result
- ▲ specific in litterature
- × nonspecific in litterature

ISH results in relation to profile similarity to SM-MHC (Y-axis) and to expression level (X-axis). Nelander, S., P. Mostad, and P. Lindahl, Prediction of cell type-specific gene modules: identification and initial characterization of a core set of smooth muscle-specific genes. Genome Res, 2003. 13(8): p. 1838-54.

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THE LEGEND IS THE MAP

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- ▽ nonselective in situ result
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GENE •

	IN SITU	IN LIT
SPECIFIC	●	▲
SELECTIVE	●	
NON-SELECTIVE	○	
NON-SPECIFIC		△

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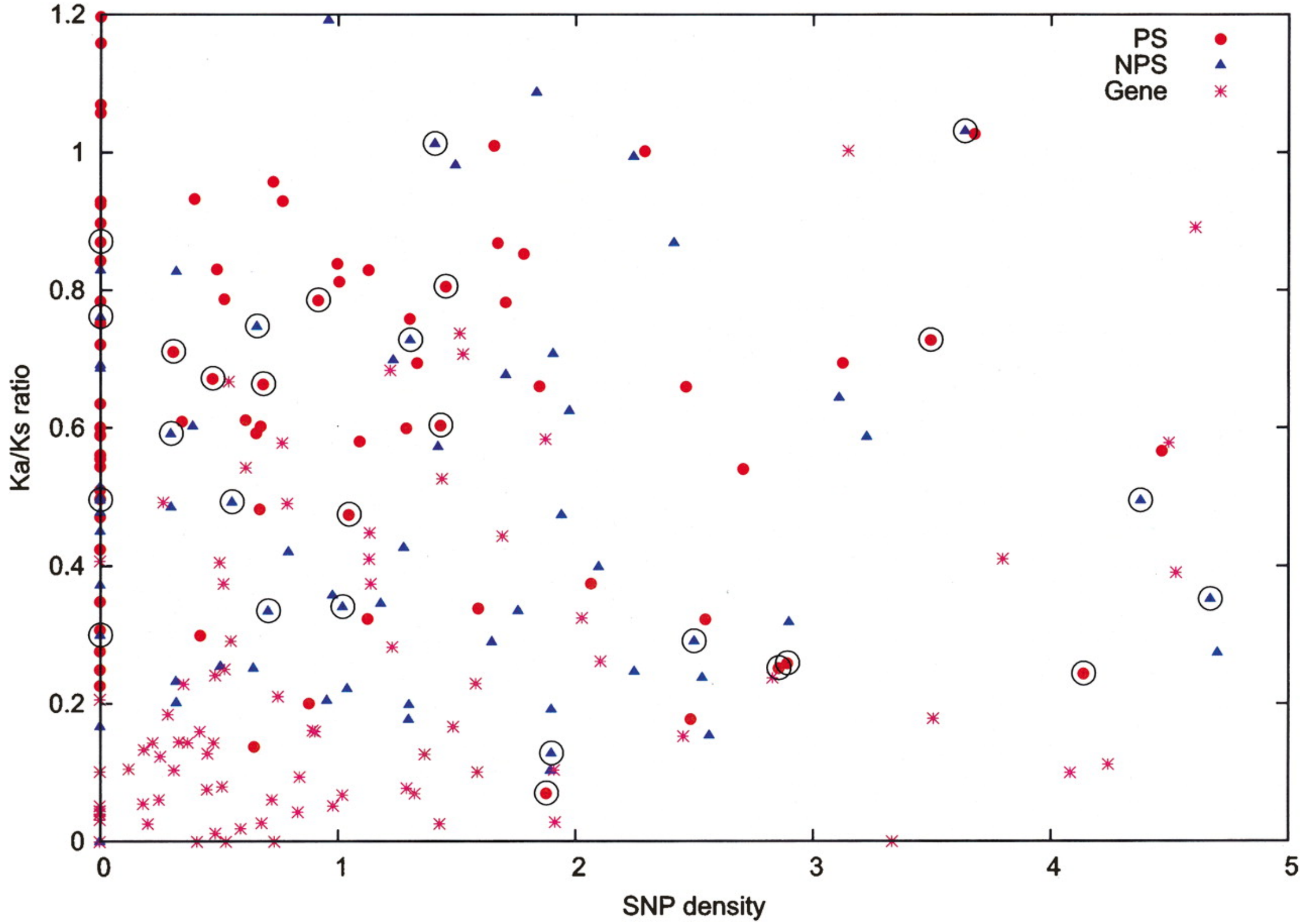
THE GLYPHS ARE CUES



Comparison of Ka/Ks ratio and SNP density for genes and pseudogenes. Zheng, D., et al., Pseudogenes in the ENCODE regions: consensus annotation, analysis of transcription, and evolution. Genome Res, 2007. 17(6): p. 839-51.

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HIERARCHICAL GLYPHS

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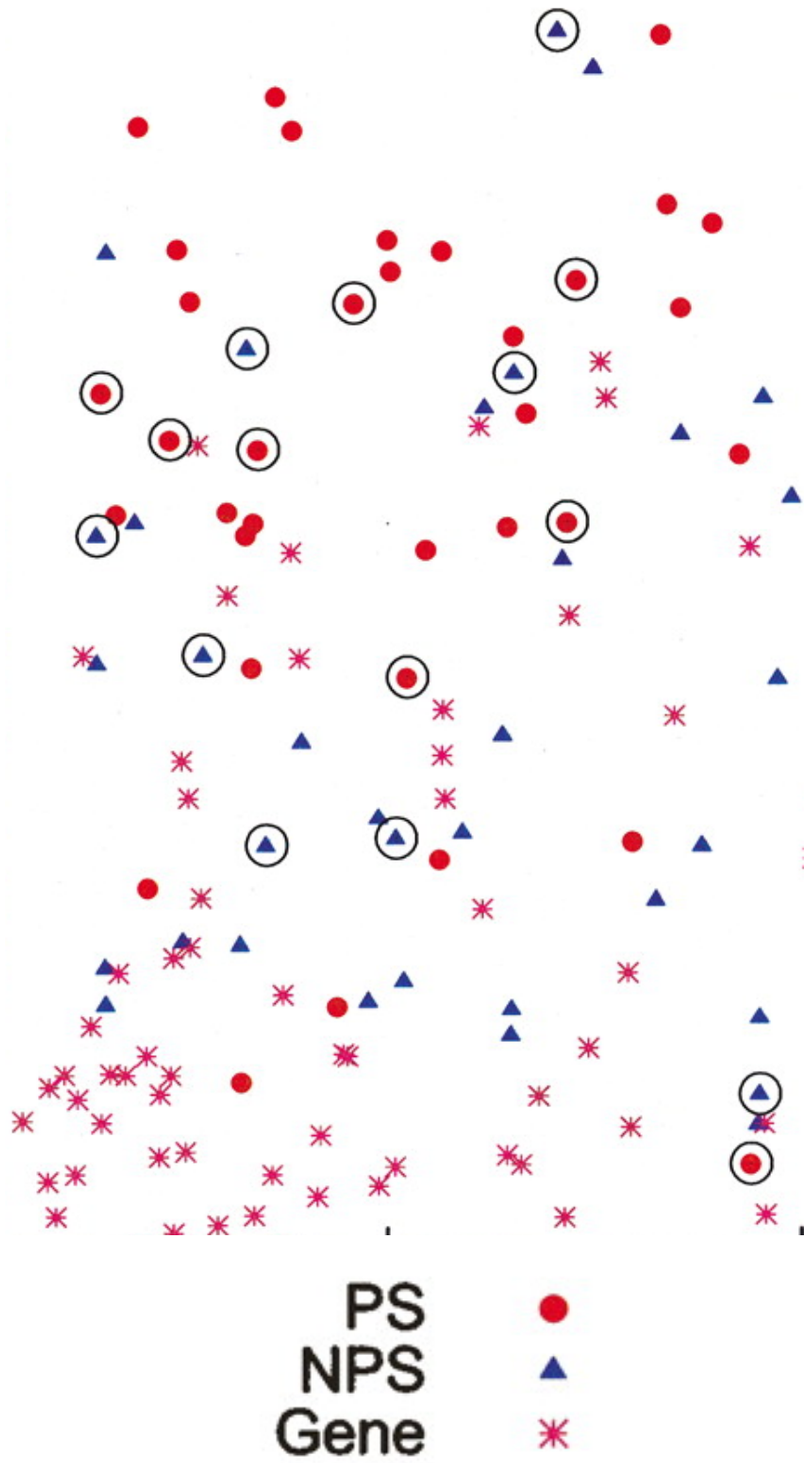
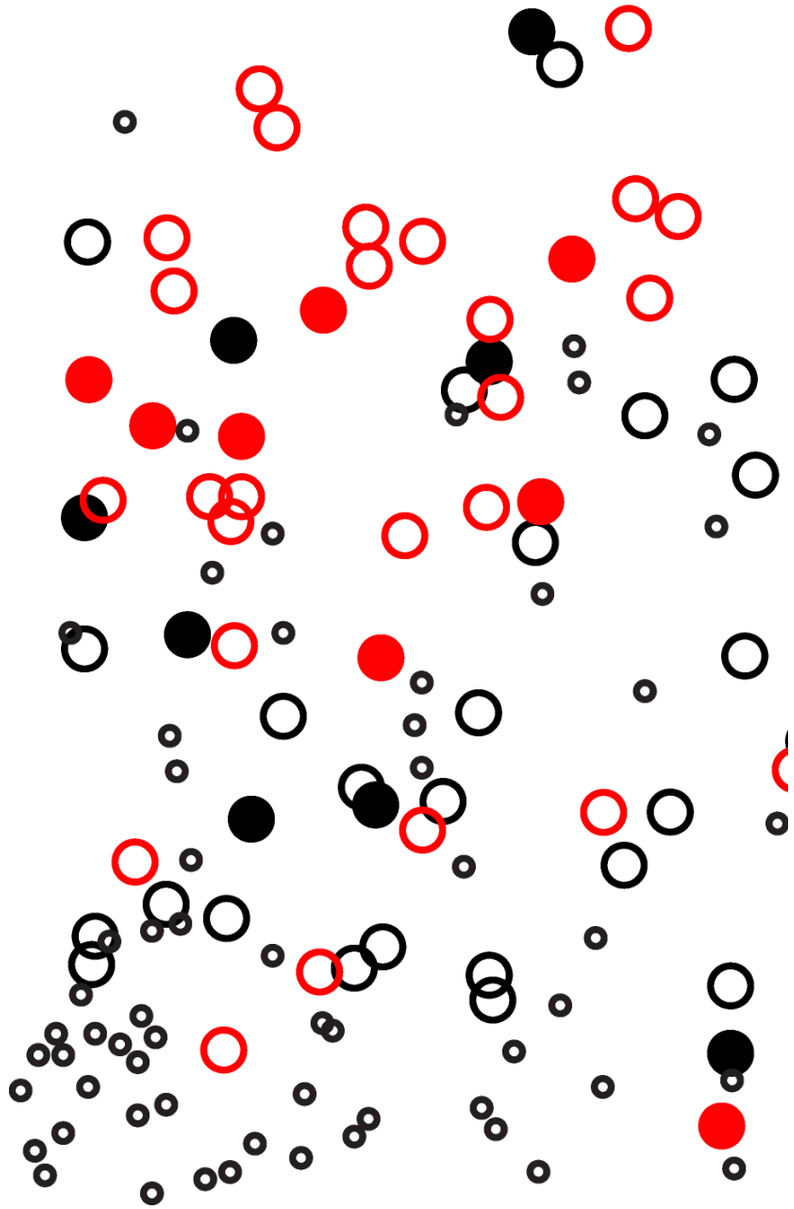
HIERARCHICAL GLYPHS





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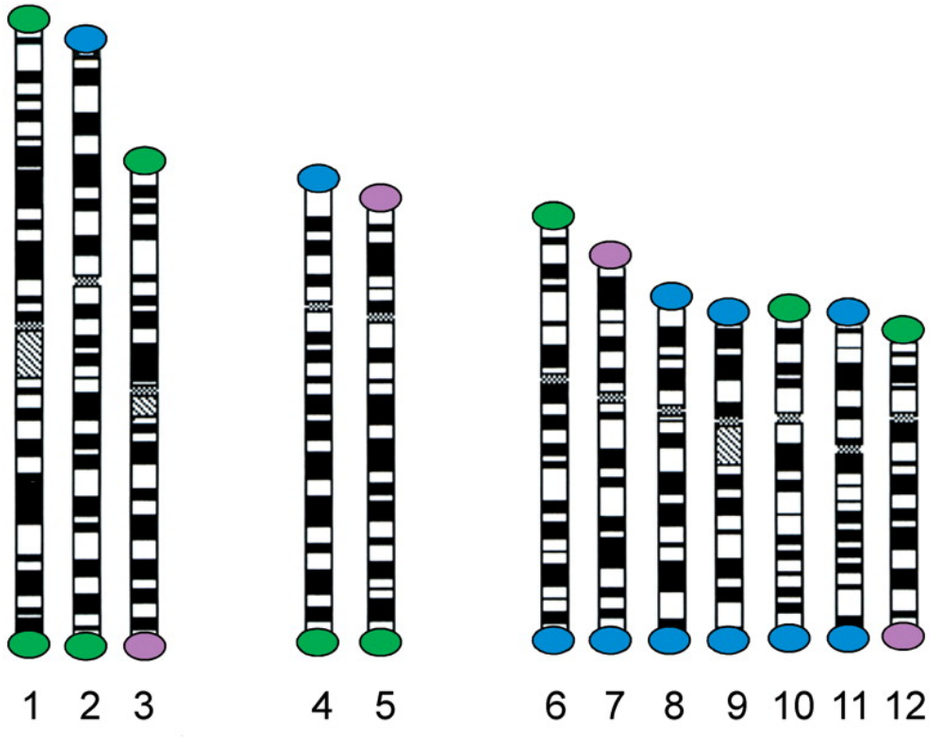
EXCESS INK



Telomere sequence gaps. Riethman, H., et al., Mapping and initial analysis of human subtelomeric sequence assemblies. Genome Res, 2004. 14(1): p. 18-28.

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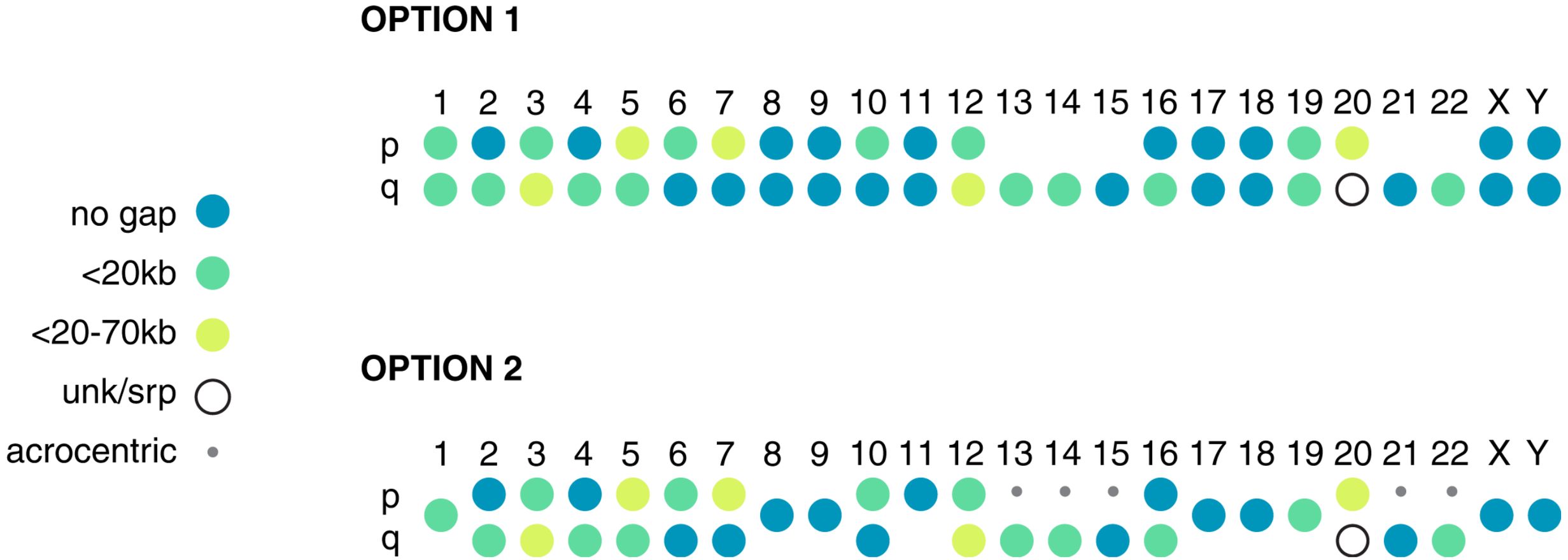
REMOVING EXCESS INK



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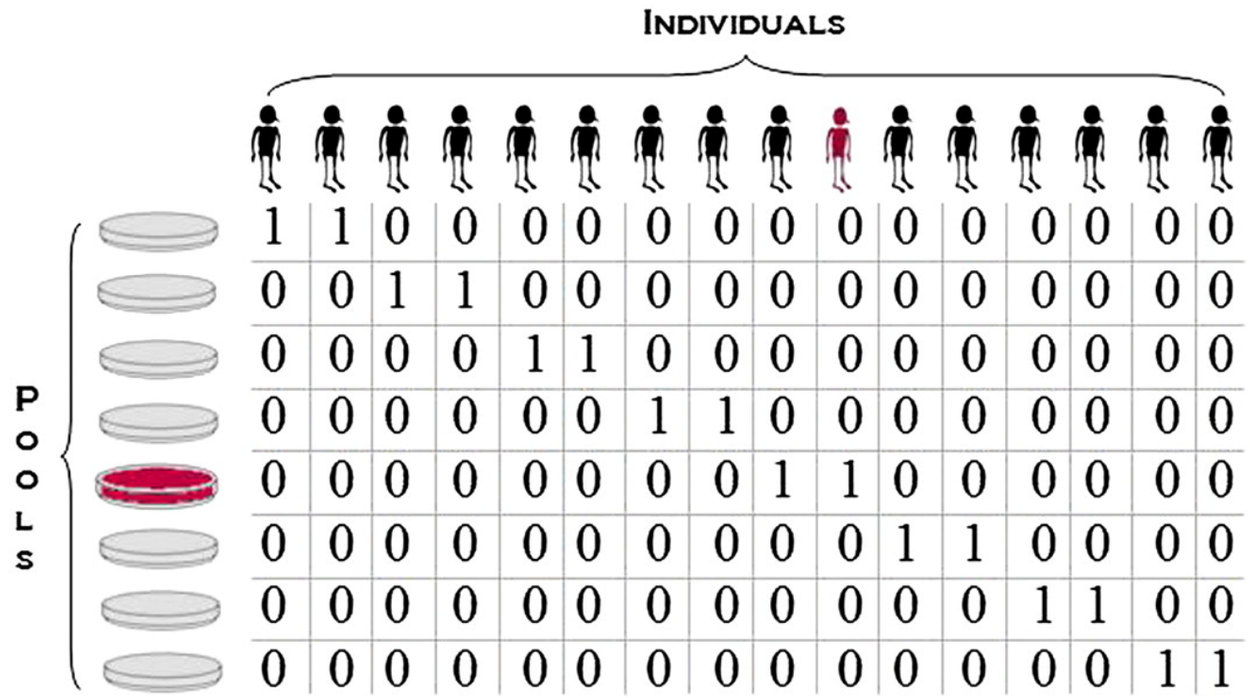
EXCESS INK COMPETES WITH MESSAGE



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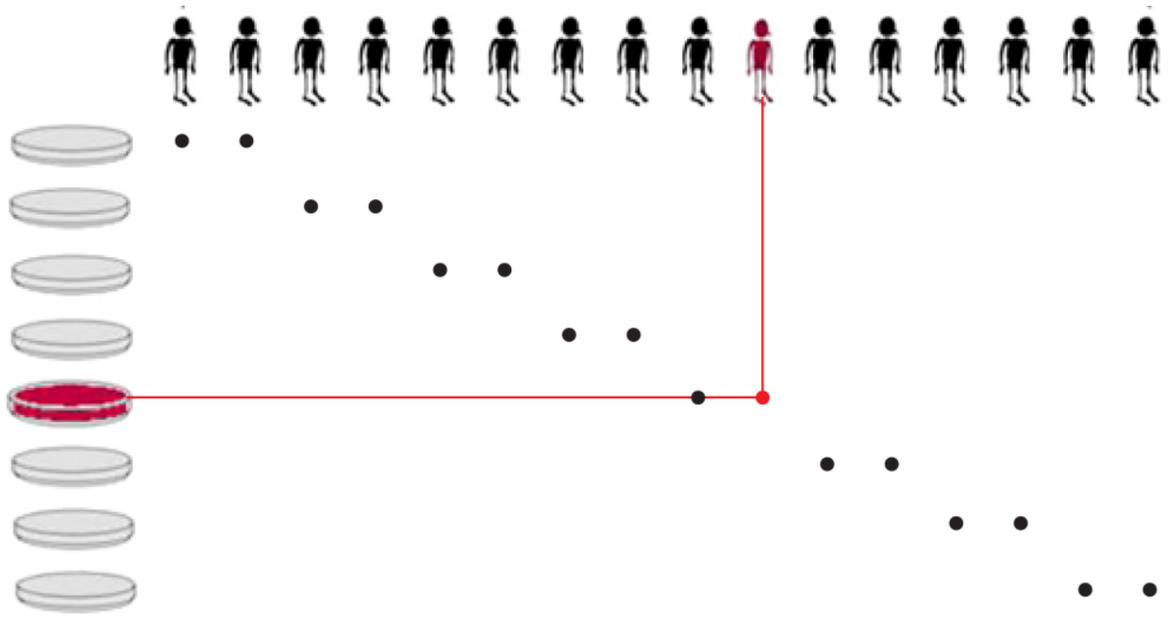

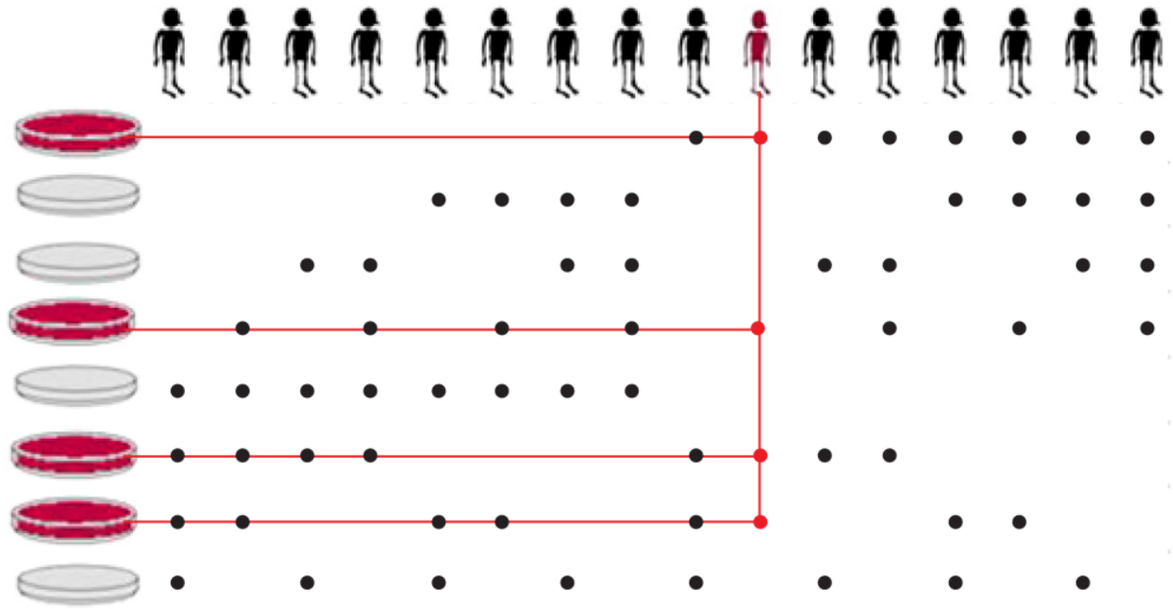

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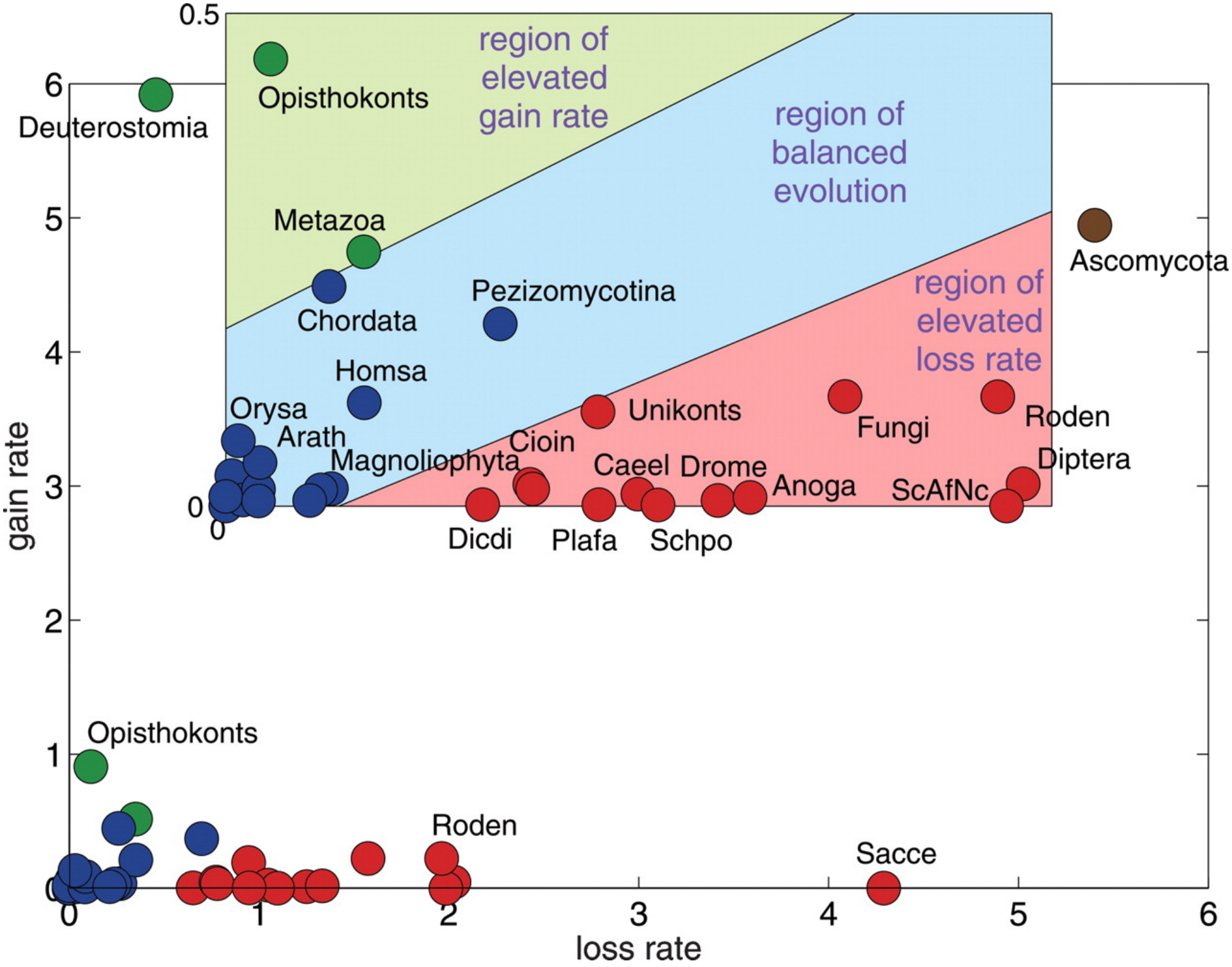

Carmel, L., et al., Three distinct modes of intron dynamics in the evolution of eukaryotes. Genome Res, 2007. 17(7): p. 1034-44.

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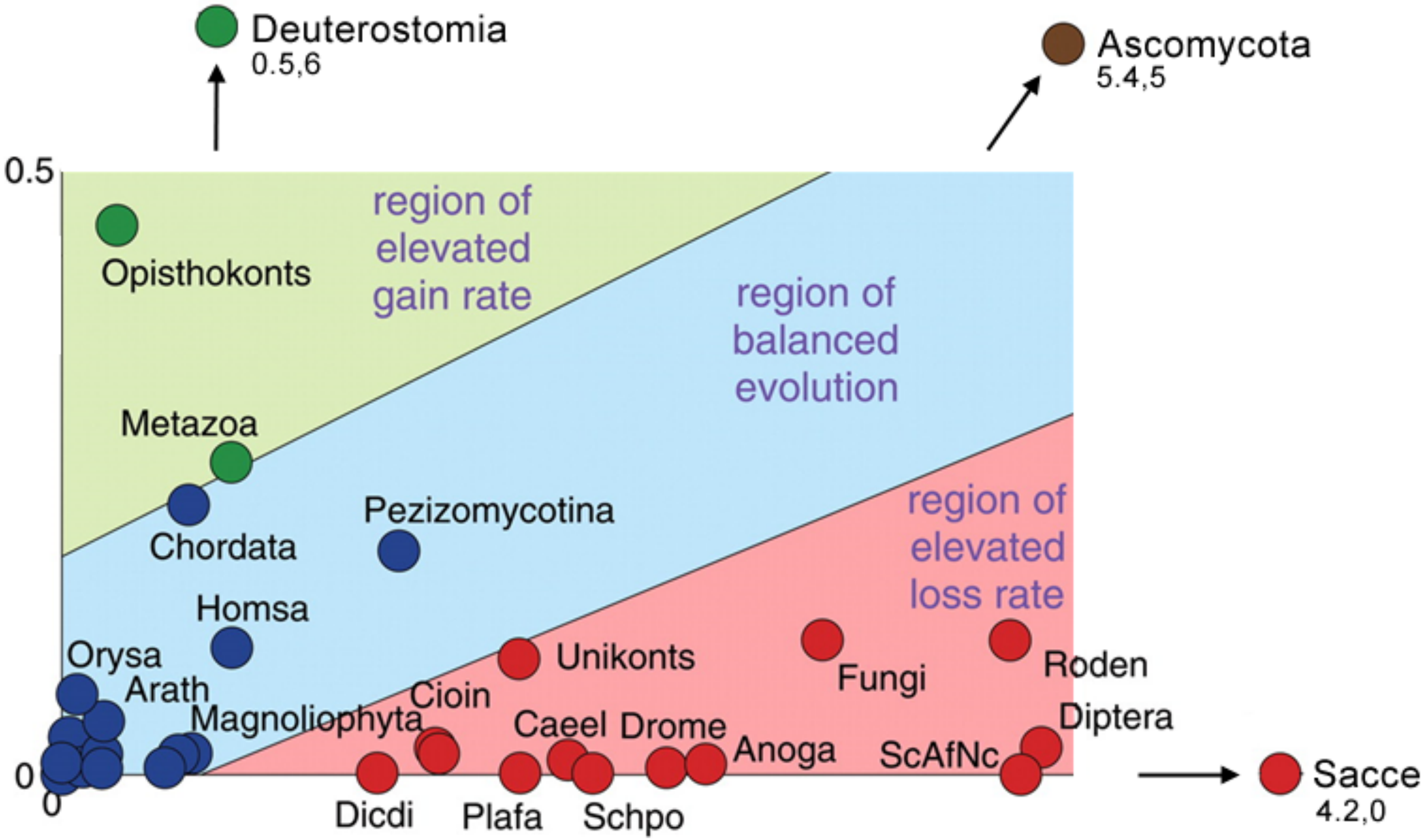

Intron gain and loss rates of eukaryotic lineages.
Carmel, L., et al., Three distinct modes of intron dynamics in the evolution of eukaryotes. Genome Res, 2007. 17(7): p. 1034-44.

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legibilityclarity**attractiveness**

GRID LAYOUT

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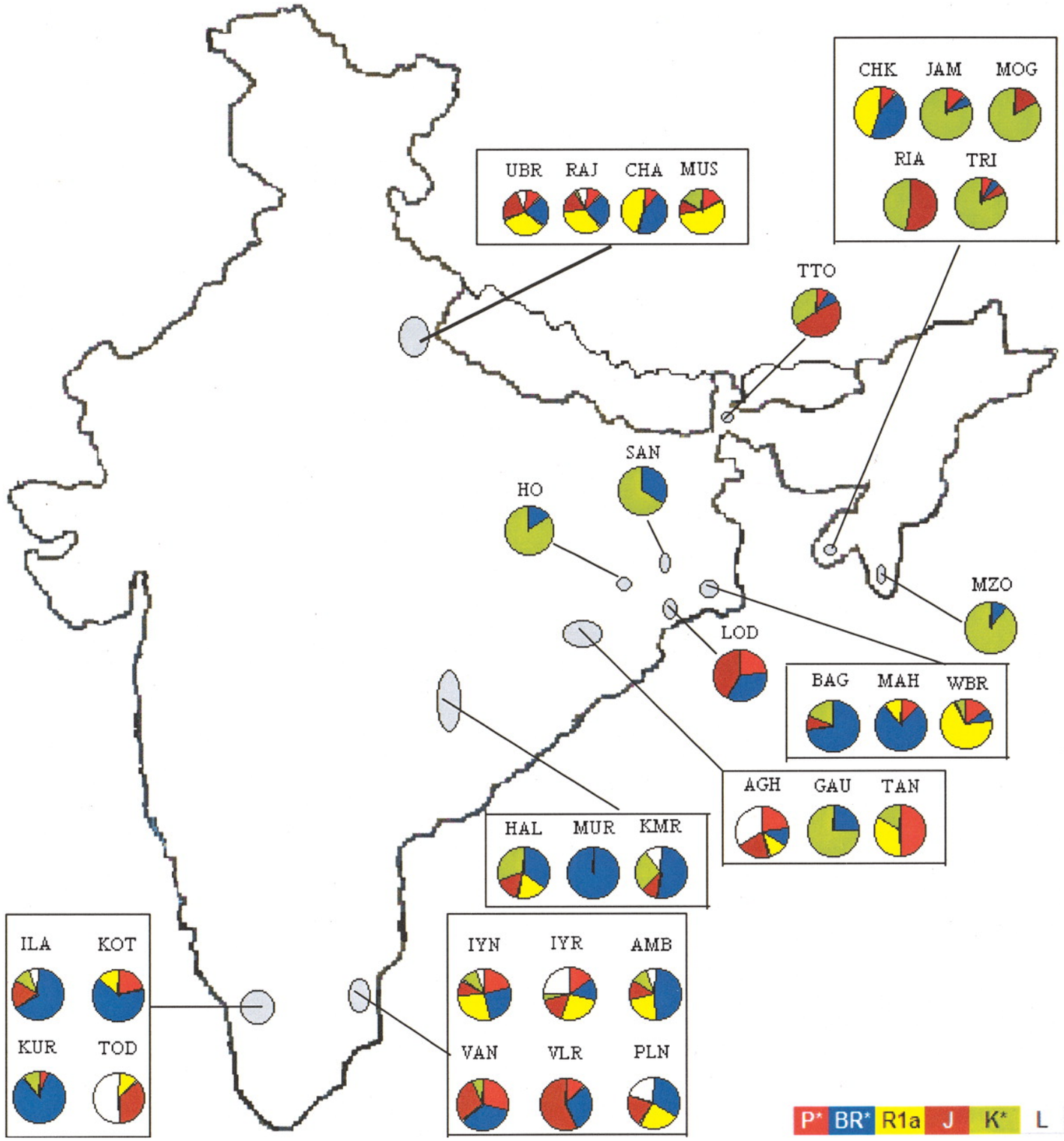

Frequencies (%) of Y-chromosomal haplogroups among ethnic populations. Basu, A., et al., Ethnic India: a genomic view, with special reference to peopling and structure. Genome Res, 2003. 13(10): p. 2277-90.

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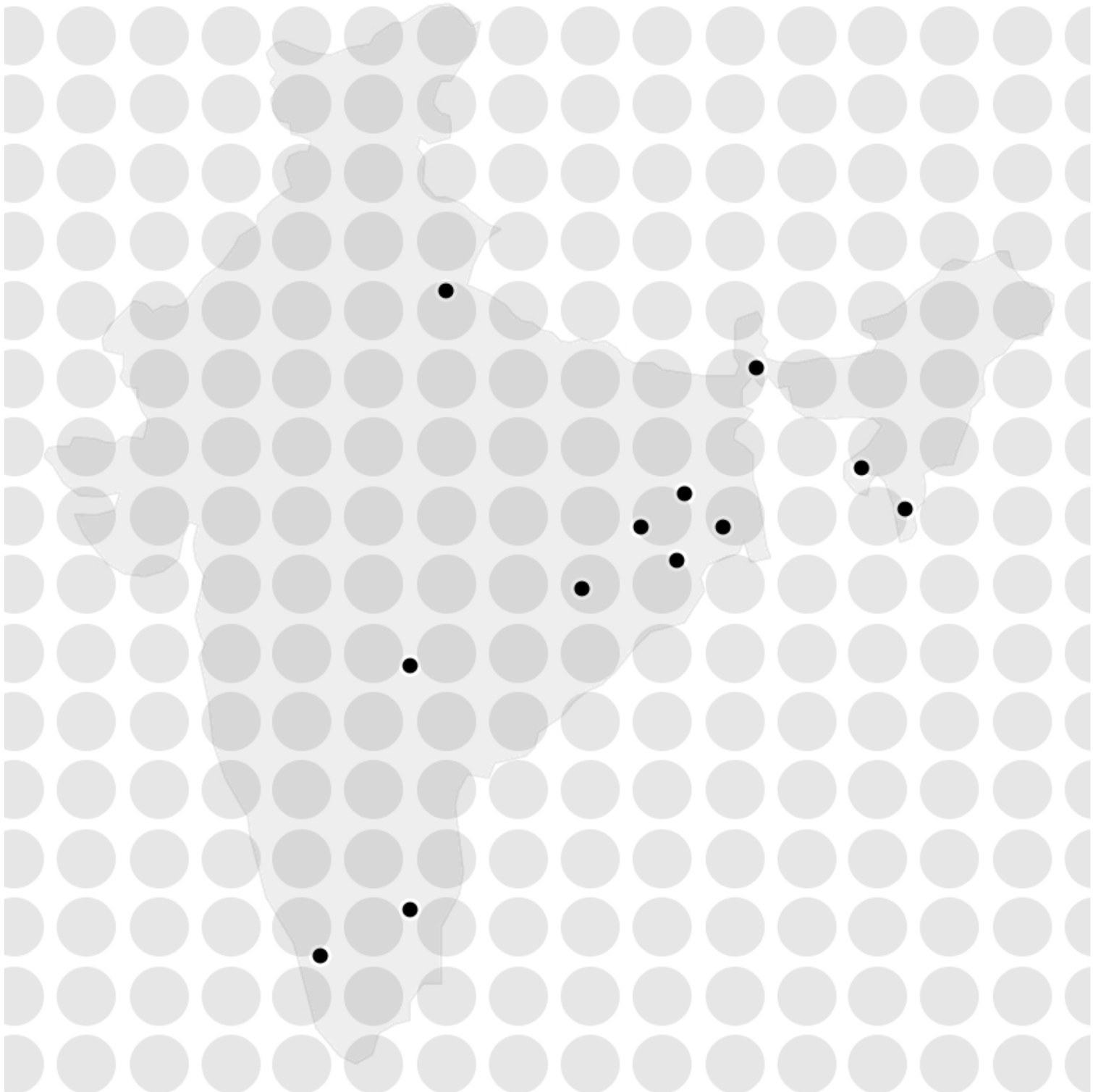

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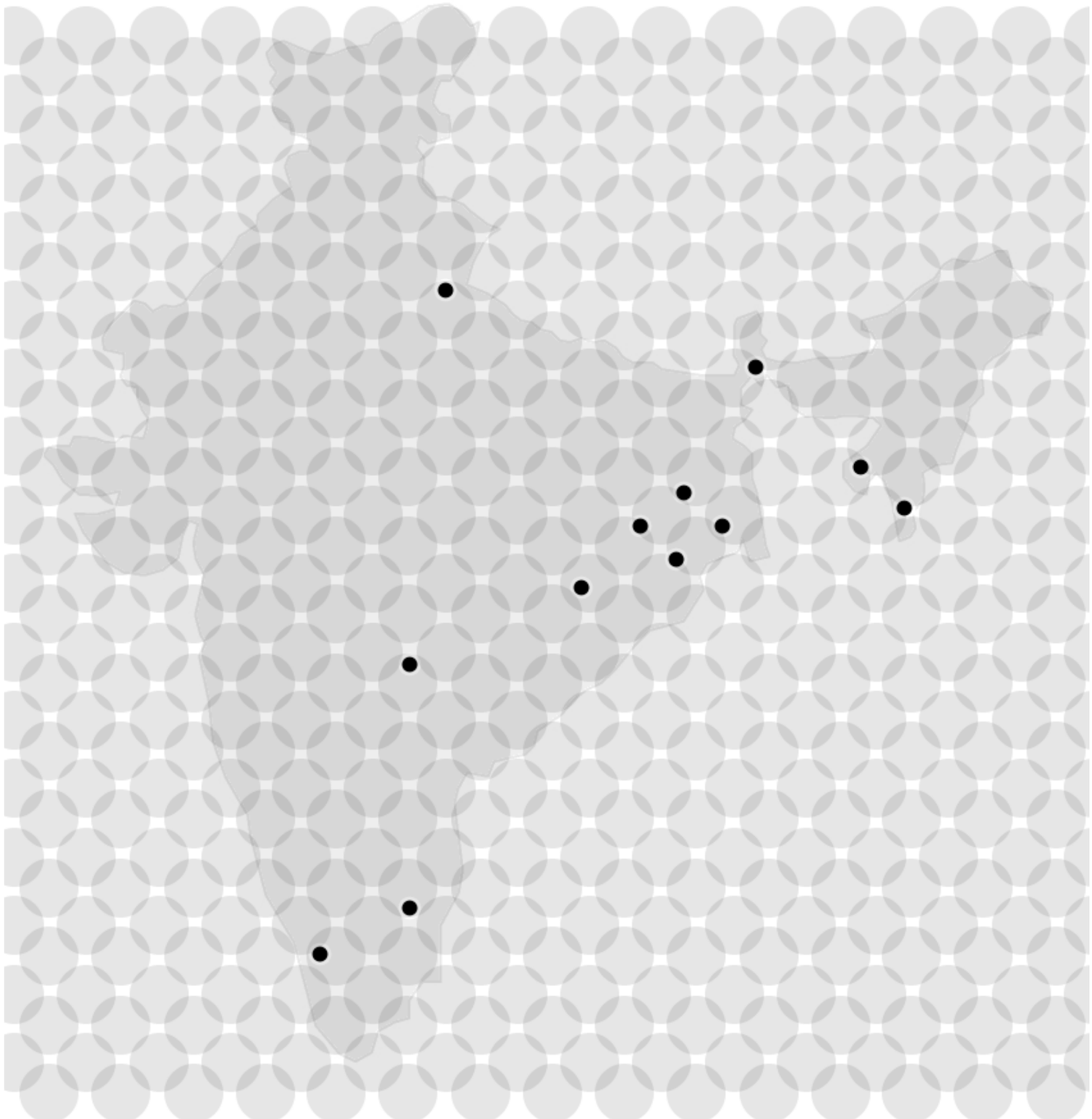

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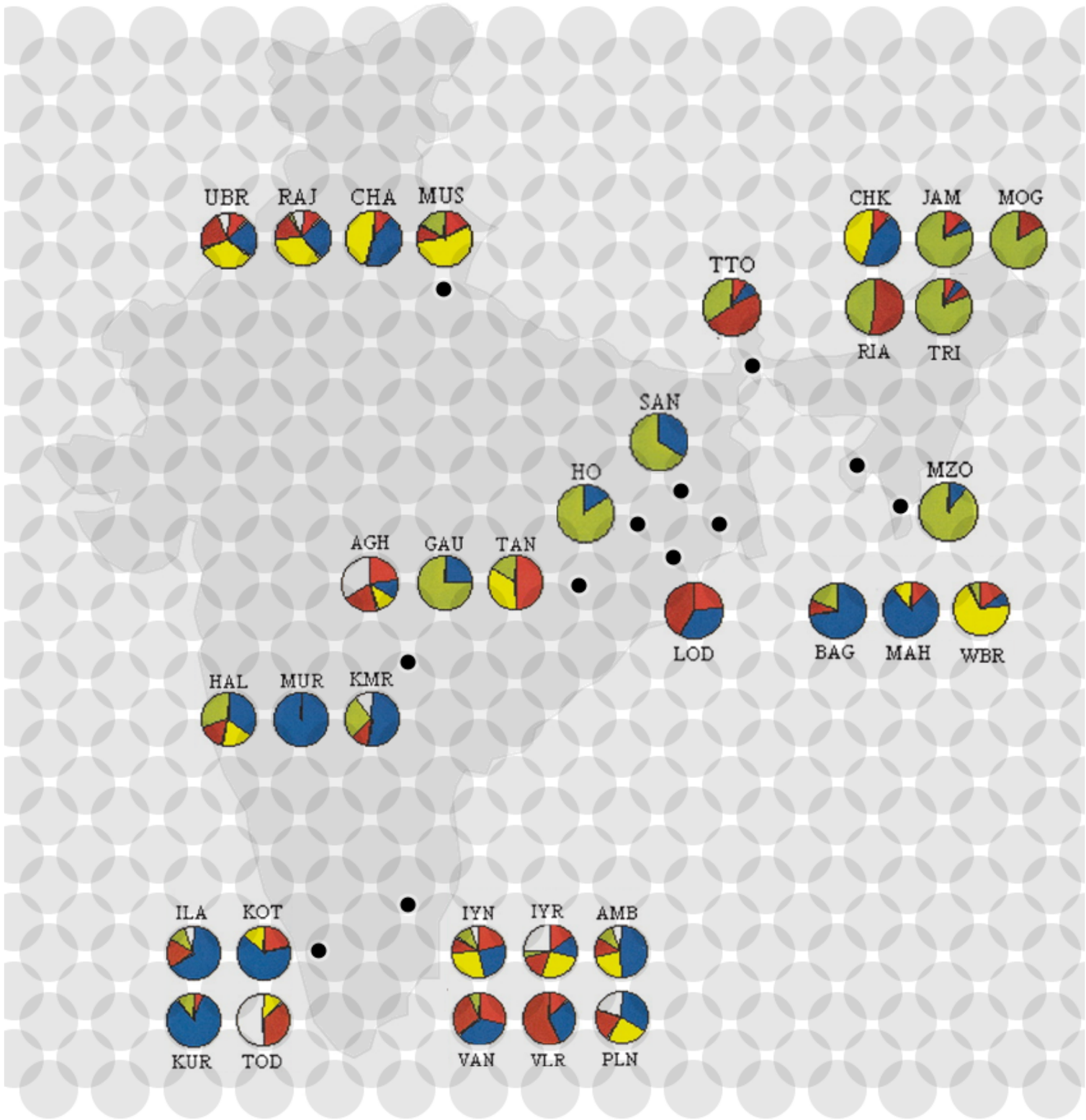

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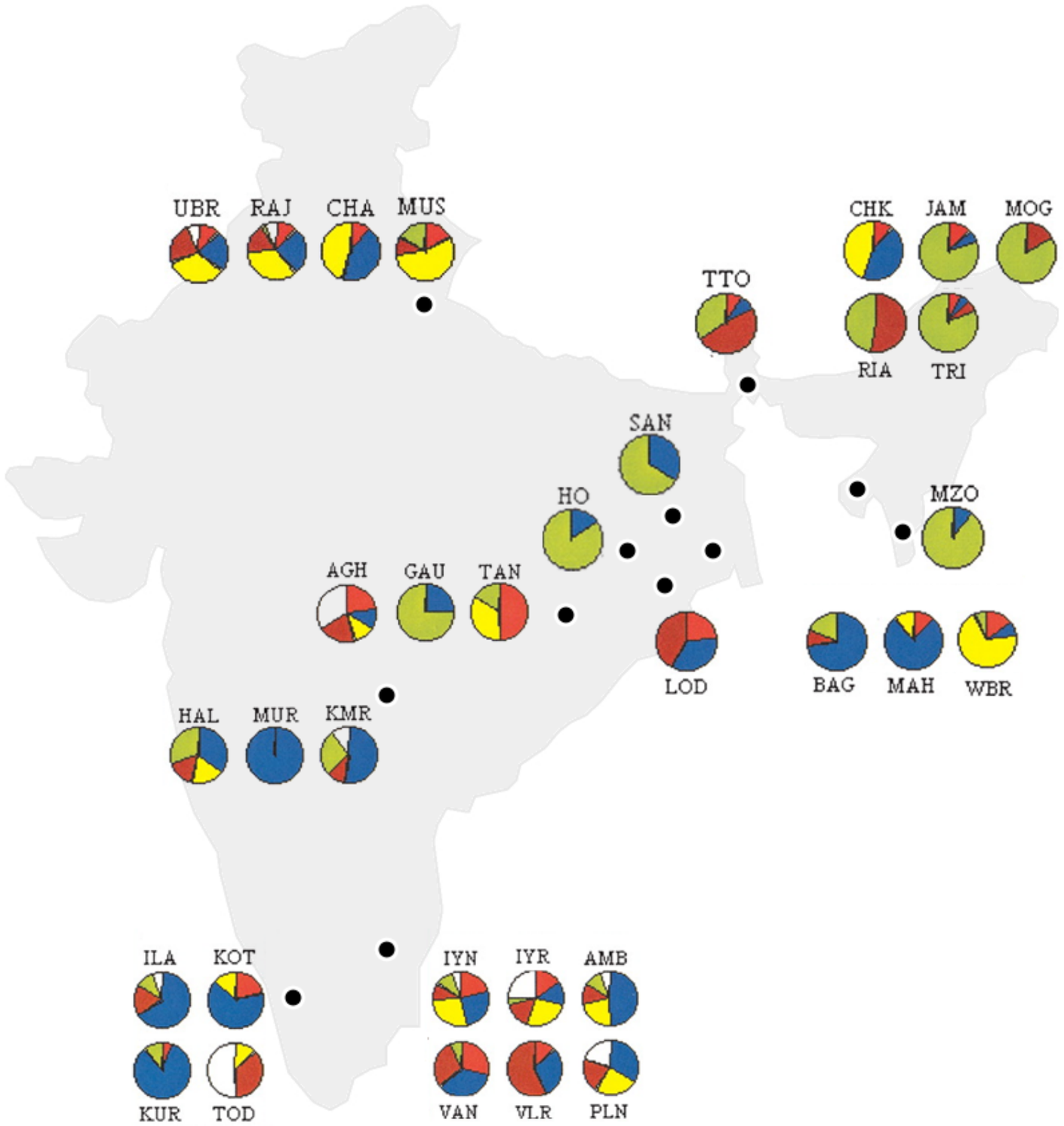

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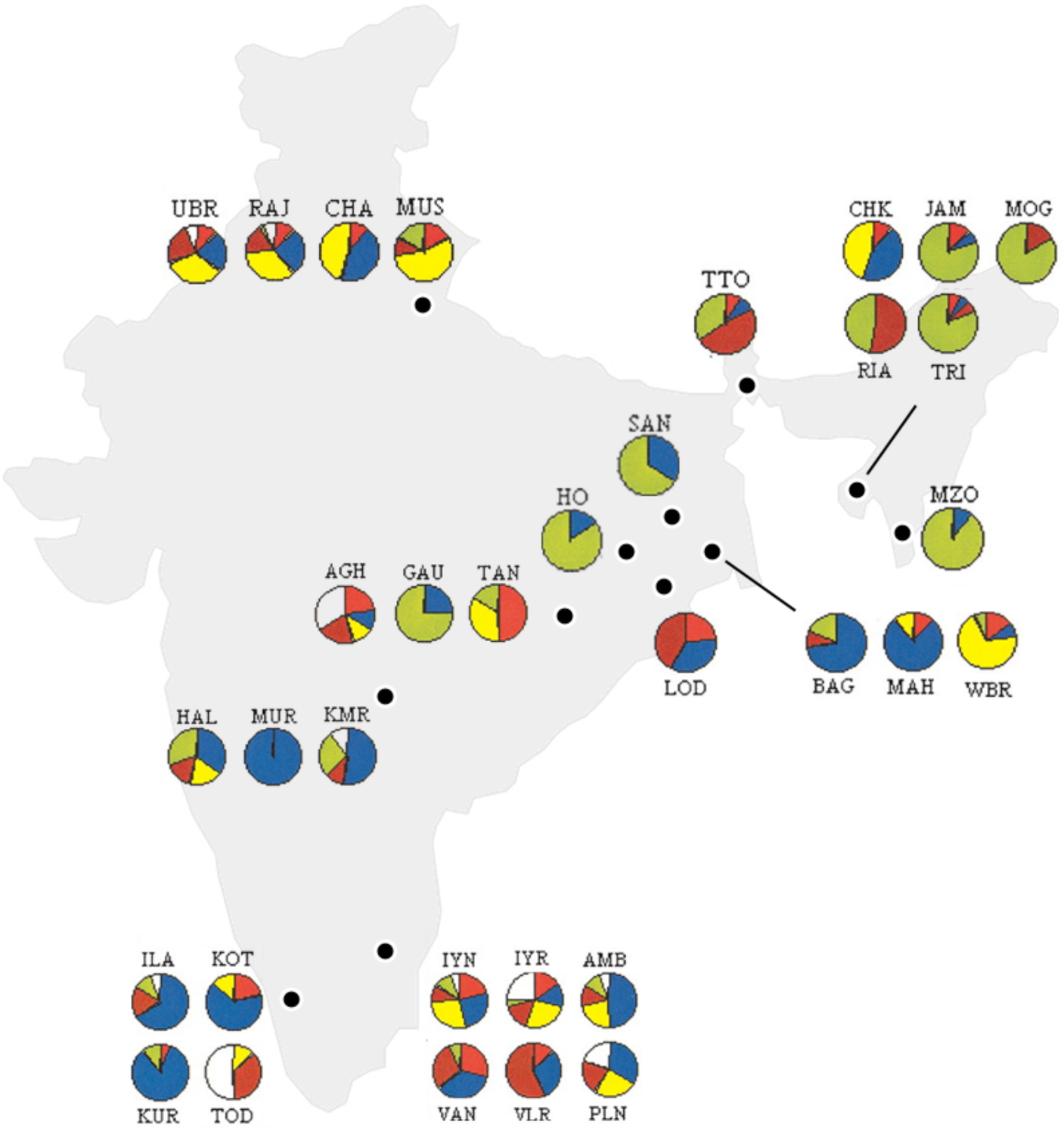

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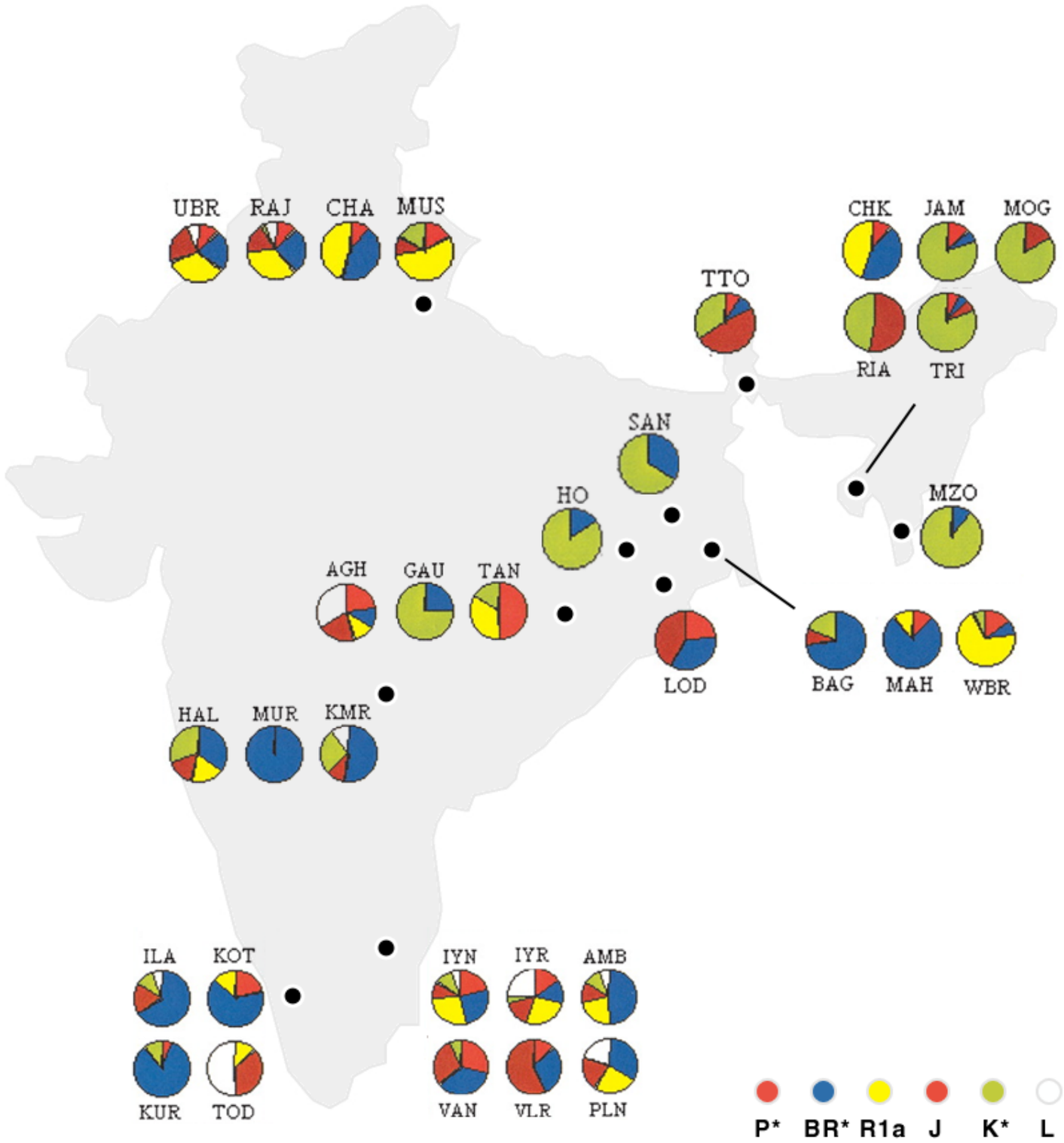

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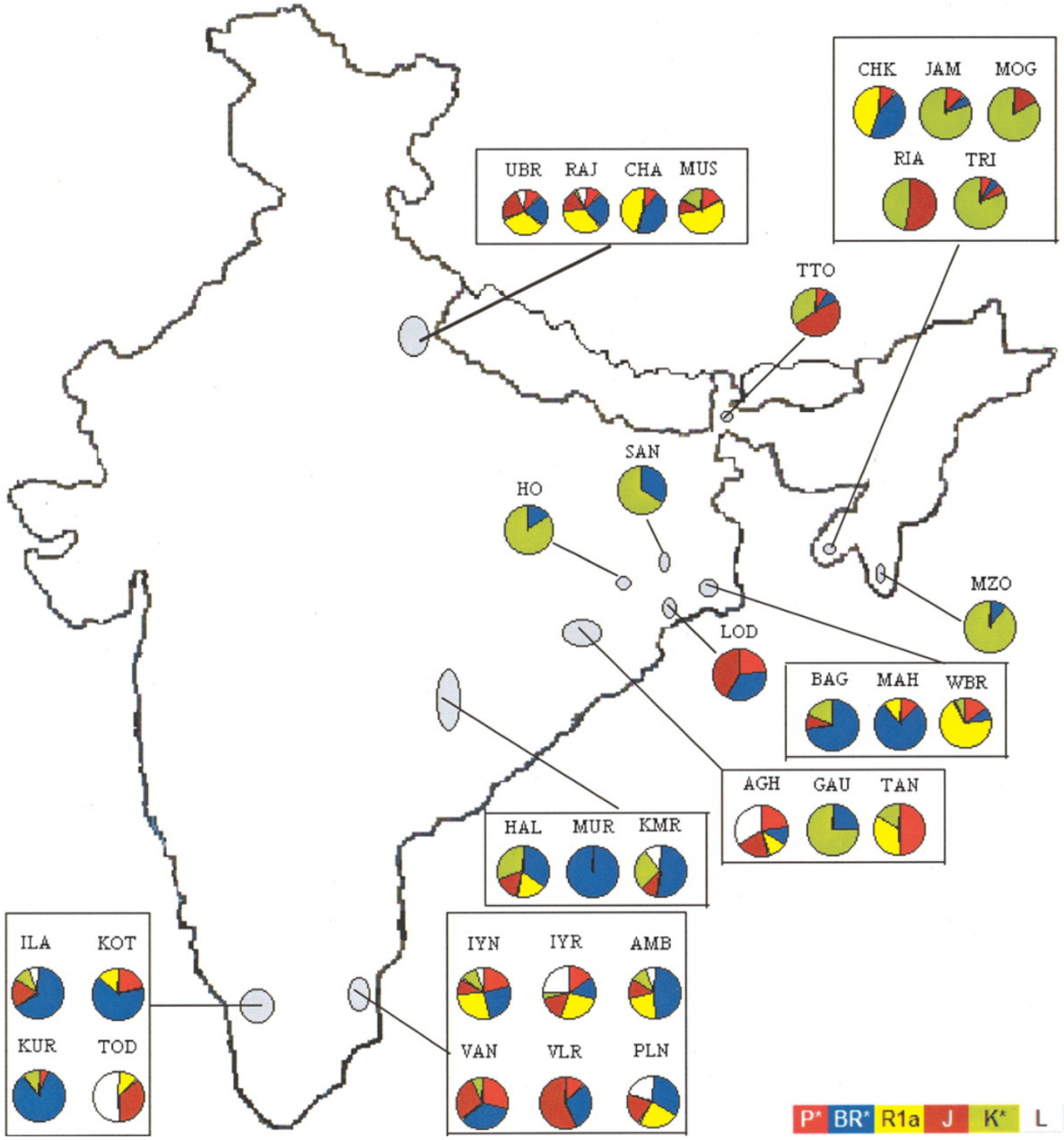

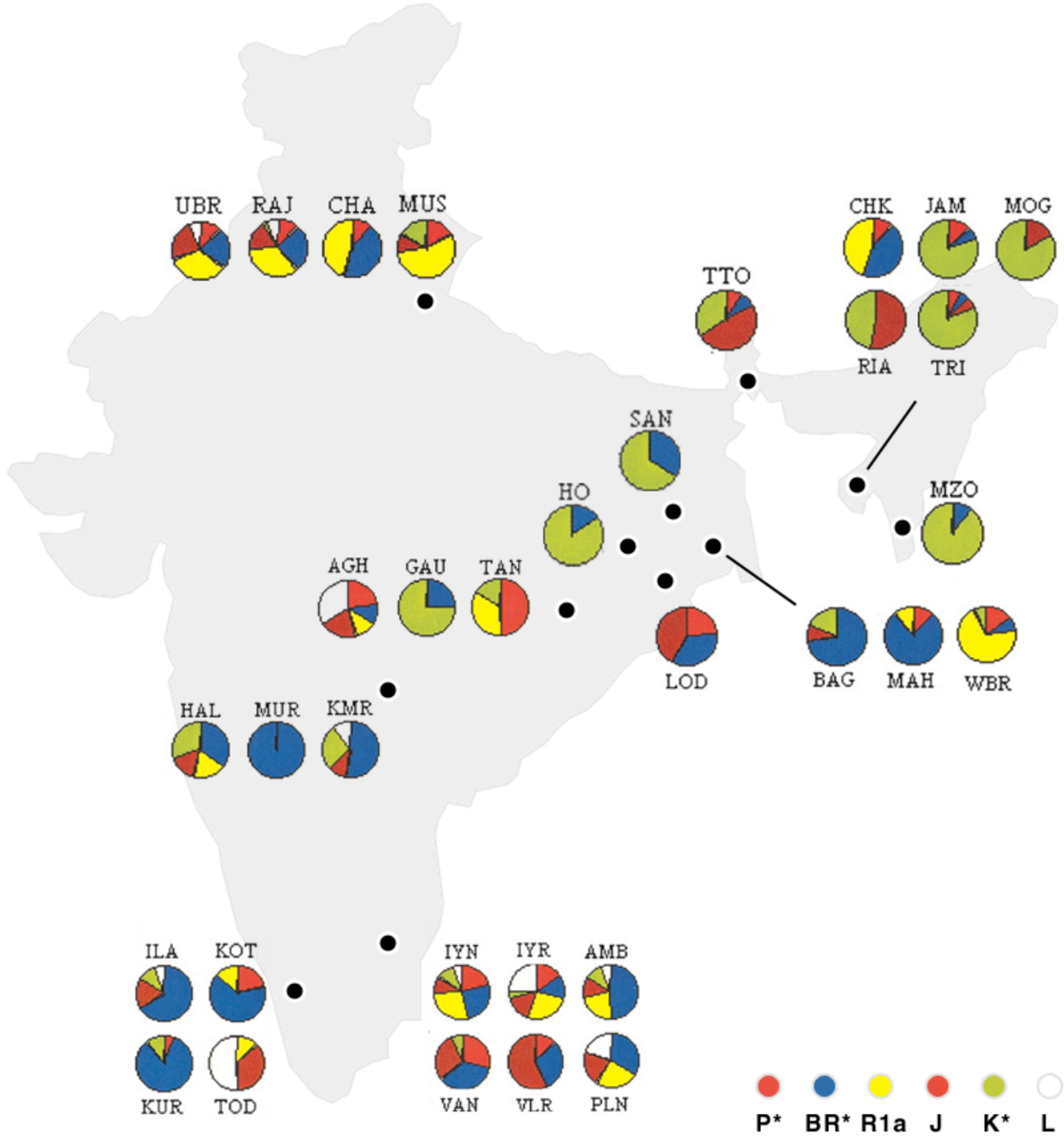

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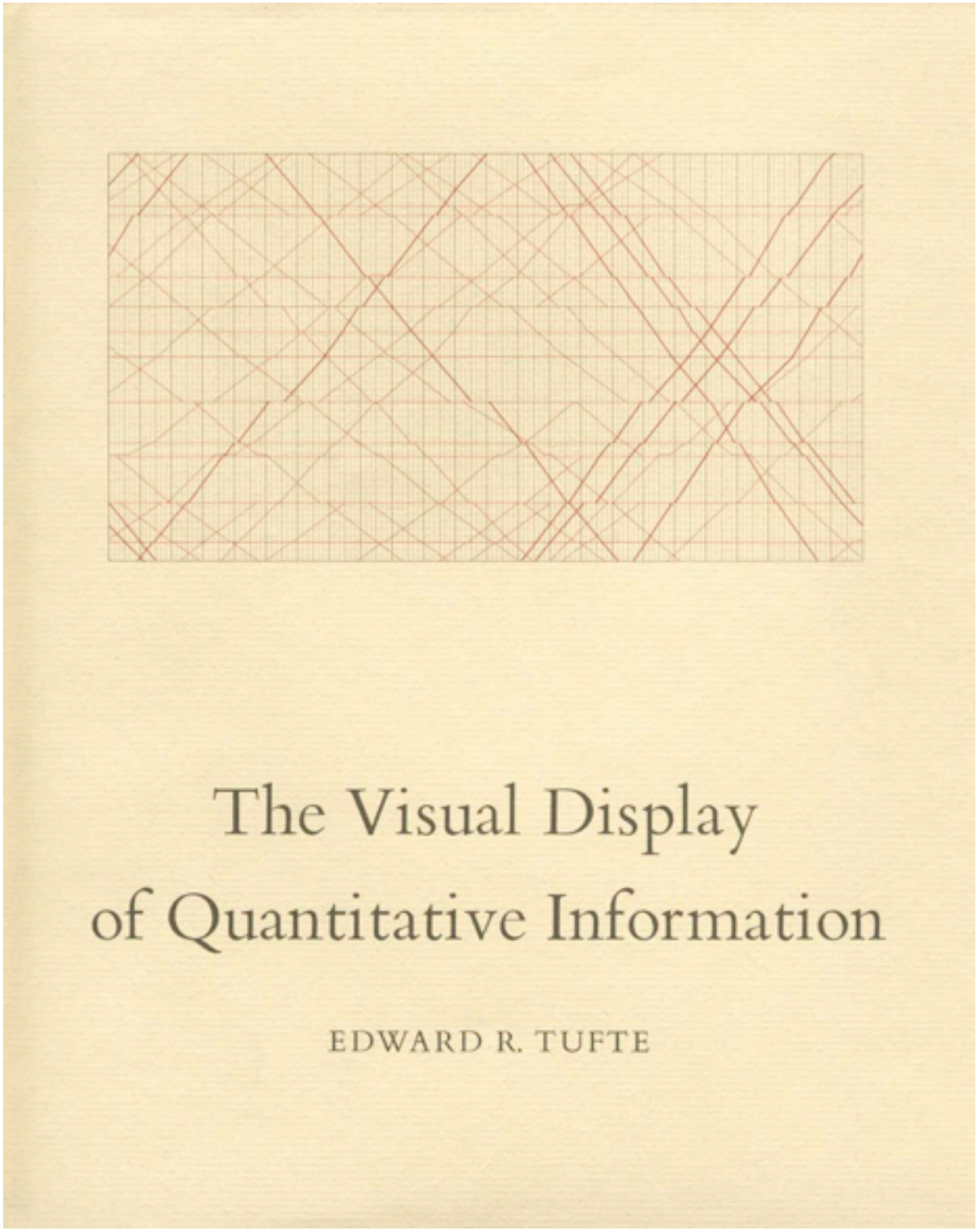
REQUIRED READING



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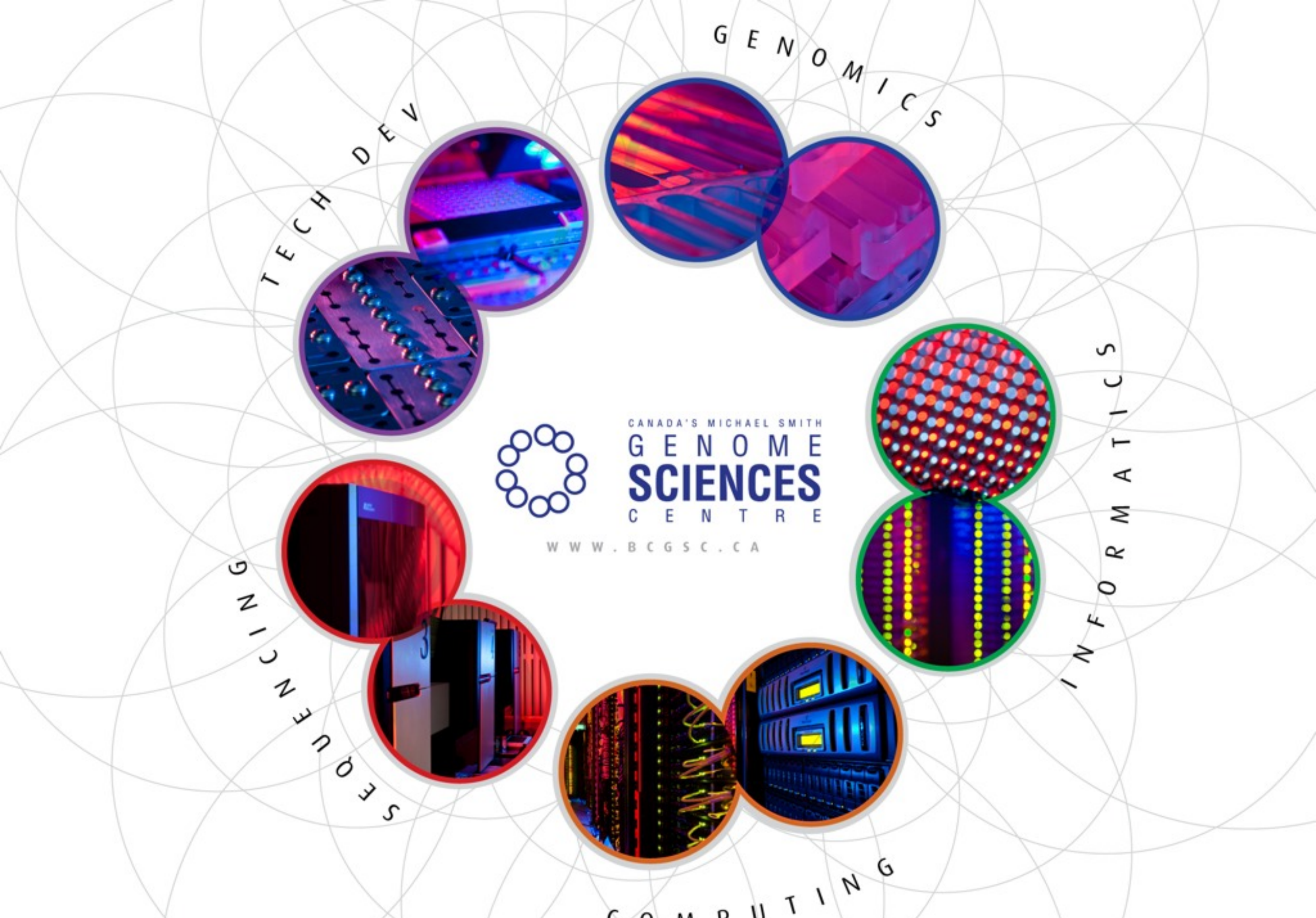
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