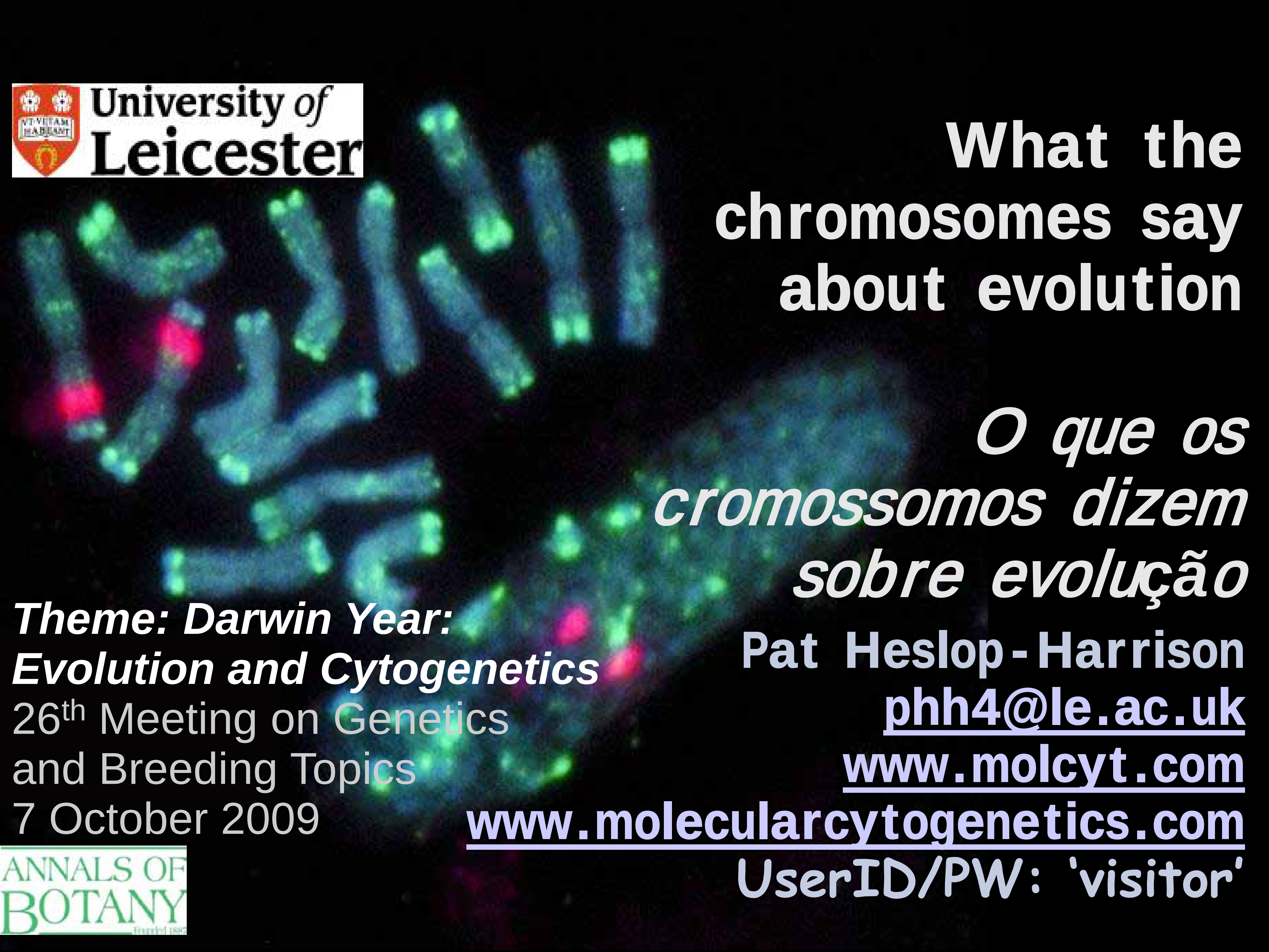


What the chromosomes say about evolution

O que os cromossomos dizem sobre evolução

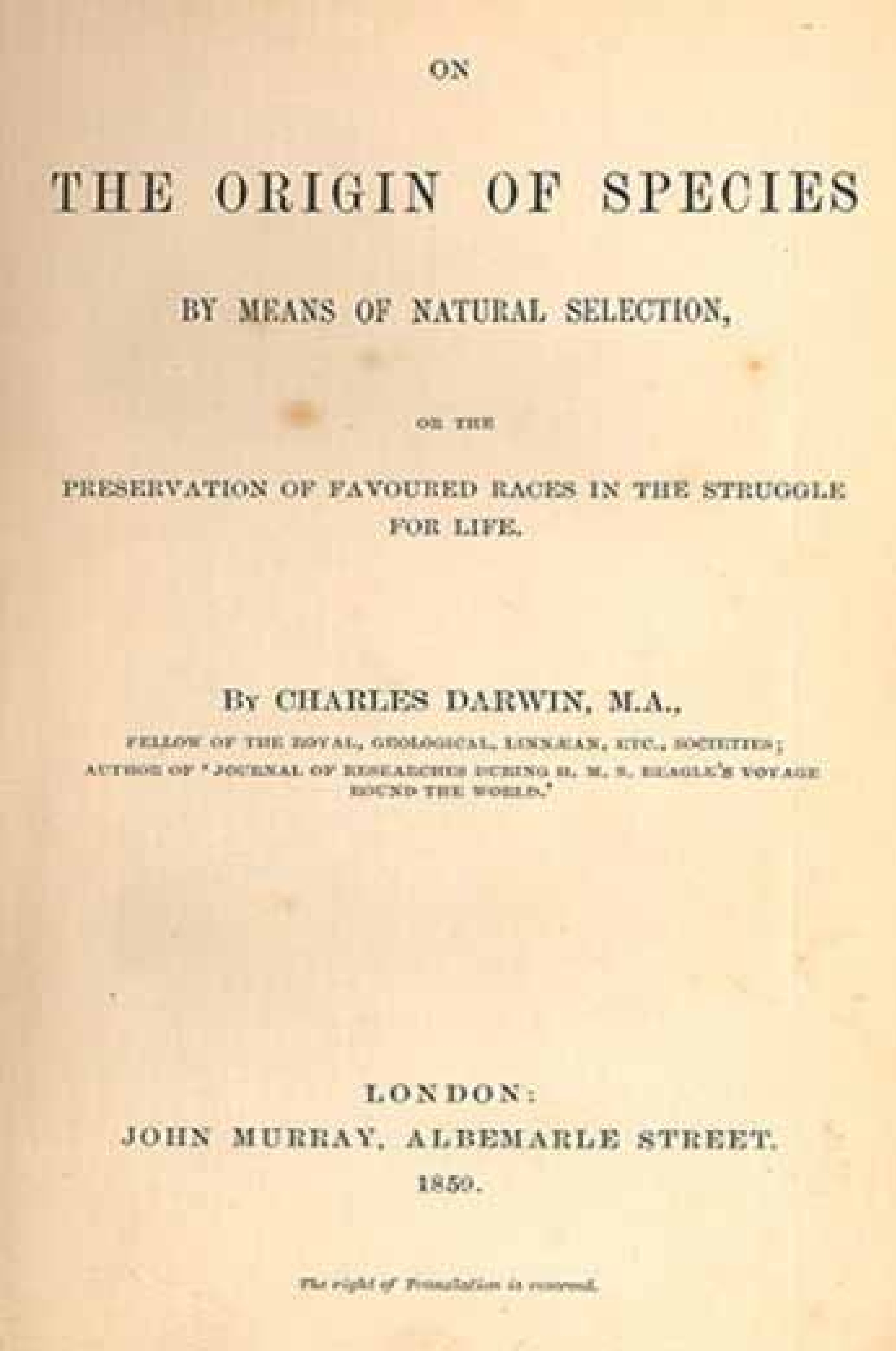
Pat Heslop-Harrison
phh4@le.ac.uk
www.molcyt.com
www.molecularcytogenetics.com

UserID/PW: 'visitor'

Theme: Darwin Year: Evolution and Cytogenetics

26th Meeting on Genetics and Breeding Topics
7 October 2009


O
EV
LUT
ON



ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

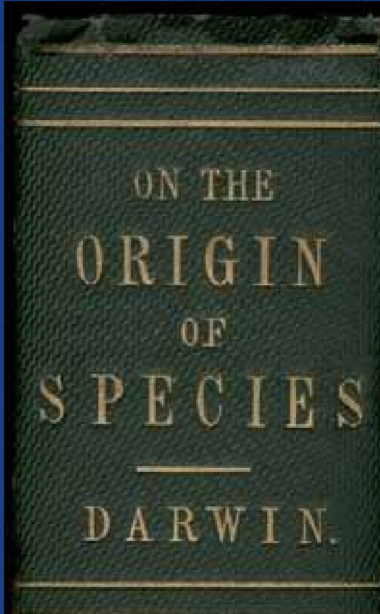
OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

By CHARLES DARWIN, M.A.,

FELLOW OF THE ROYAL, GEOLOGICAL, LINNÆAN, ETC., SOCIETIES;
AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE ROUND THE WORLD.'

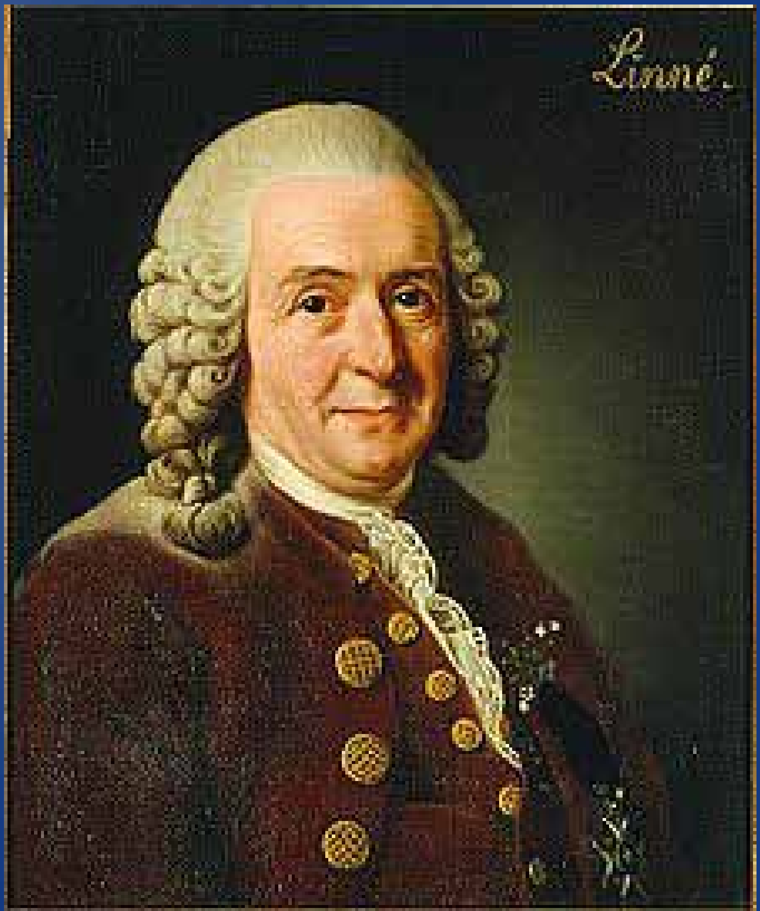
LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.



- Before Charles Darwin, 'biology' was a mixture of description and philosophy
- Many antecedents: Linnaeus; Lamarck; his grandfather Erasmus Darwin – and from ancient civilization: You eat something that looks similar to something you know; you treat your disease with something similar!
- Contemporaries: Wallace, Hooker(s), Galton ...
- Charles Darwin was the first to develop testable hypotheses and was the first experimental biologist

Carl Linnaeus 1707-1778

- *Species Plantarum* 1753
- Father of modern taxonomy
- And what became ecology



Some ... believe that species undergo modification, and that the existing forms of life have descended by true generation from pre-existing forms. Passing over authors from the classical period to that of Buffon ... Lamarck was the first man whose conclusions on this subject excited much attention. This justly-celebrated naturalist first published his views in 1801 ...

Darwin, 1861. Origin 3rd Edition (4th Edition more on Buffon).

Jean-Baptiste Lamarck (1744-1829)

Early proponent of 'evolution' in accordance with natural laws

Flora française 1788; *Système des animaux sans vertèbres* 1801

Inheritance of acquired characters

Change through use or disuse

Increasing complexity

Darwin: “Lamarck ... upholds the doctrine that all species, including man, are descended from other species.”

Lamarck ... upholds the doctrine that all species, including man, are descended from other species. He first did the eminent service of arousing attention to the probability of all change in the organic as well as in the inorganic world being the result of law, and not of miraculous interposition.

Lamarck seems to have been chiefly led to his conclusion on the gradual change of species, by the difficulty of distinguishing species and varieties, by the almost perfect gradation of forms in certain organic groups, and by the analogy of domestic productions.

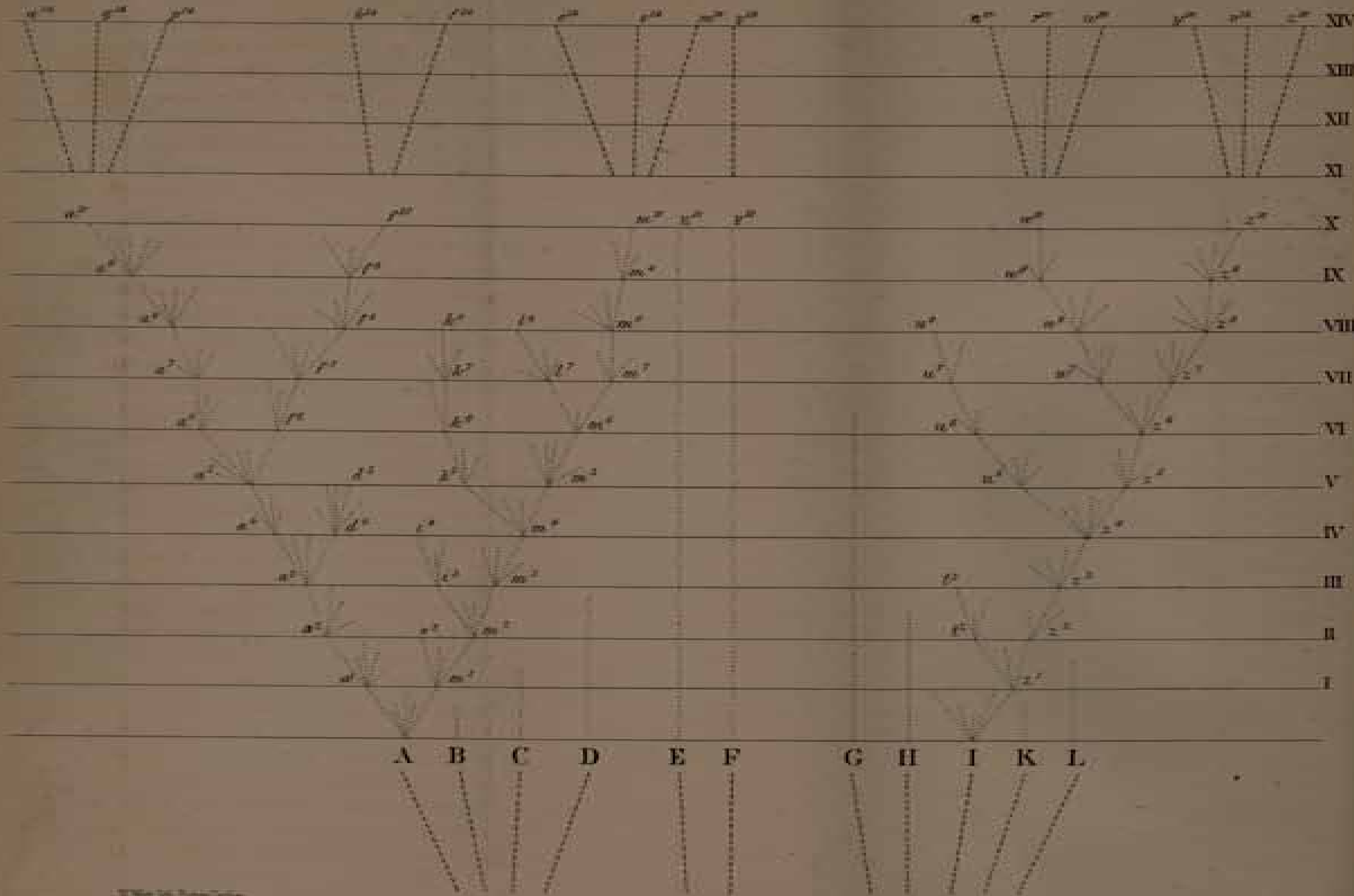
Two phases of research, as defined by Francis Darwin 1899. The botanical work of Darwin. Annals of Botany os-13: x-xix.

FIRST Phase of Research

Based on observation, compilation and deduction, leading to evolutionary conclusions

Darwin (writing to Asa Gray in 1857) "nature does not lie".

Published as "On the Origin of Species by Natural Selection" (1859)


XIV
XIII
XII
XI
X
IX
VIII
VII
VI
V
IV
III
II
I
A
B
C
D
E
F
G
H
I
K
L

The final paragraph of the Origin 1/3

It is interesting to contemplate a tangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent upon each other in so complex a manner, have all been produced by laws acting around us.

The final paragraph of the Origin 2/3

These laws, taken in the largest sense, being Growth with reproduction; Inheritance which is almost implied by reproduction; Variability from the indirect and direct action of the conditions of life, and from use and disuse; a Ratio of Increase so high as to lead to a Struggle for Life, and as a consequence to Natural Selection, entailing Divergence of Character and the Extinction of less improved forms. Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows.

The final paragraph of the Origin 3/3

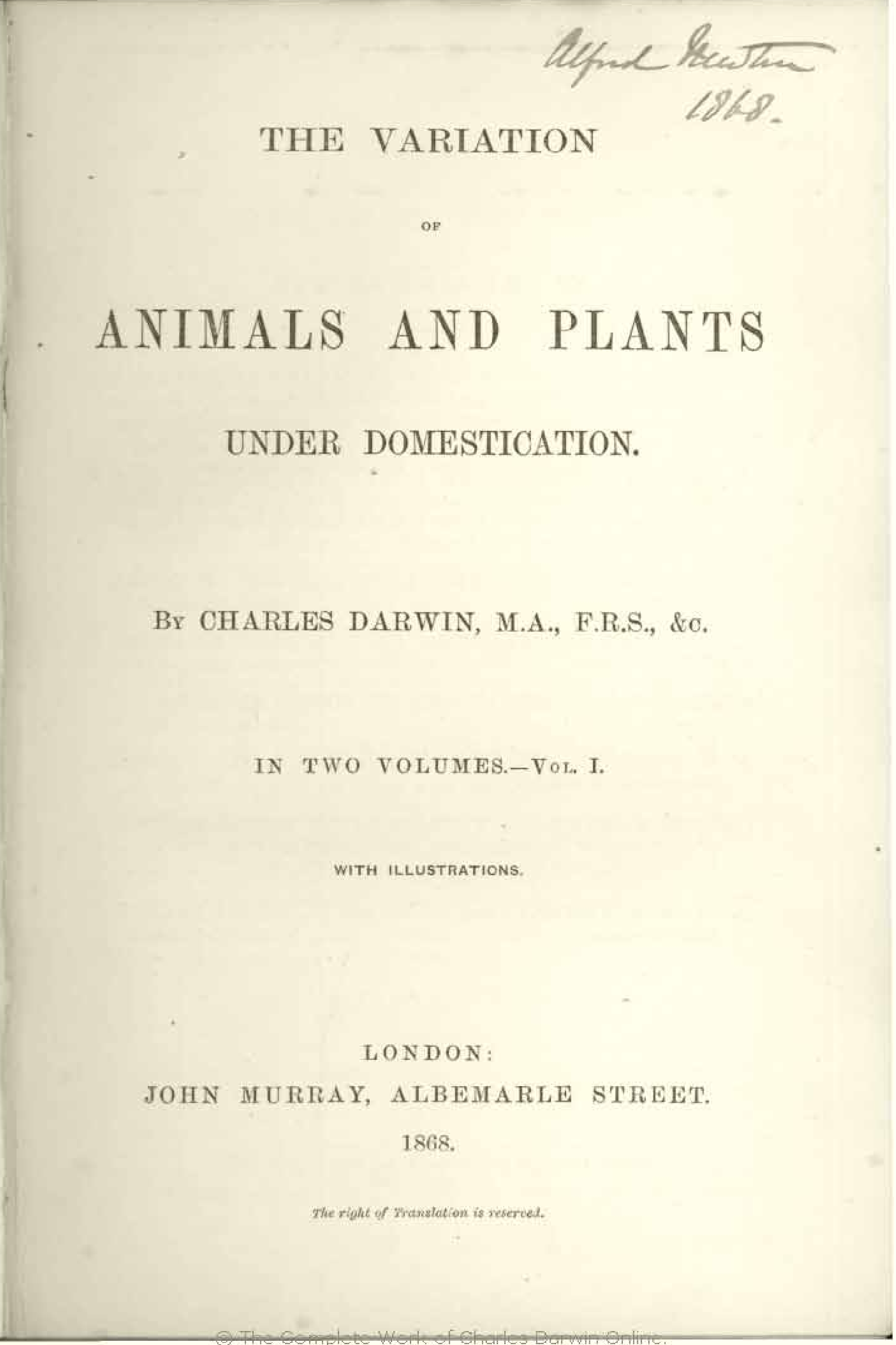
There is grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone circling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being evolved.

Charles Darwin

Second Phase of Research

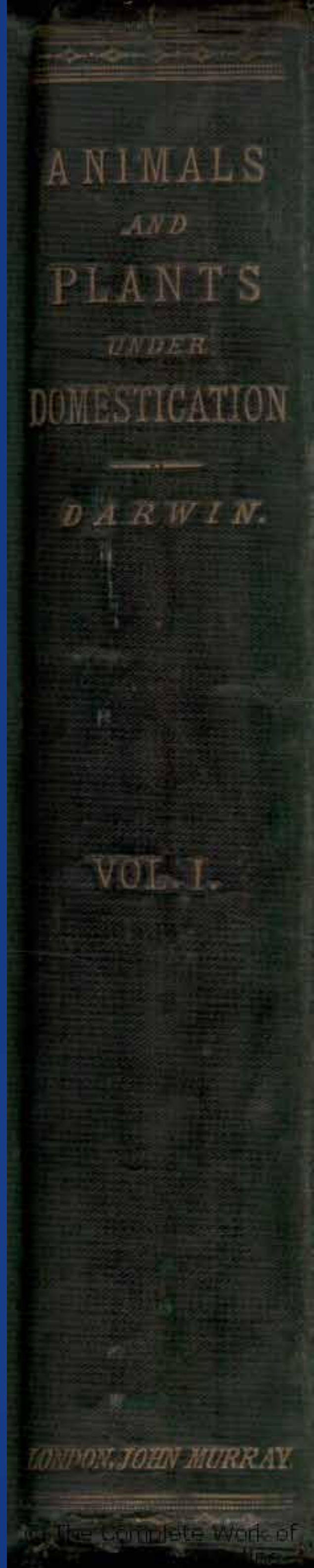
'Experimental' period

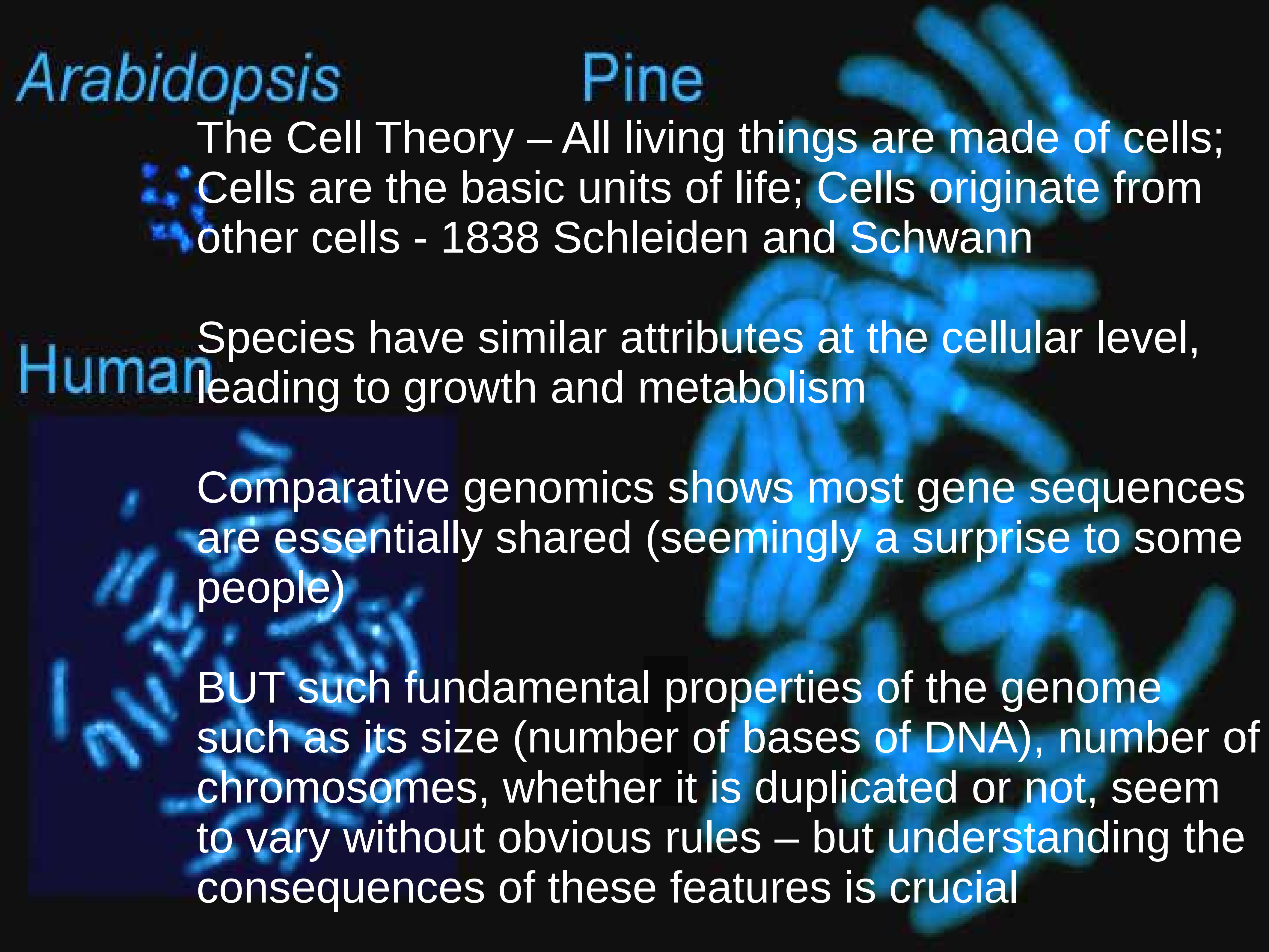
Work on cross- and self-fertilization, and climbing, insectivorous and domesticated plants, where he could test the conclusions of his evolutionary work and investigate causes and consequences of speciation and extinction -



26th Meeting on Genetics and Breeding Topics

Theme: Darwin Year: Evolution and Cytogenetics





The Cell Theory – All living things are made of cells; Cells are the basic units of life; Cells originate from other cells - 1838 Schleiden and Schwann

Species have similar attributes at the cellular level, leading to growth and metabolism

Comparative genomics shows most gene sequences are essentially shared (seemingly a surprise to some people)

BUT such fundamental properties of the genome such as its size (number of bases of DNA), number of chromosomes, whether it is duplicated or not, seem to vary without obvious rules – but understanding the consequences of these features is crucial

Theme: Darwin Year: Evolution and Cytogenetics

26th Meeting on Genetics and Breeding Topics

What the Chromosomes say

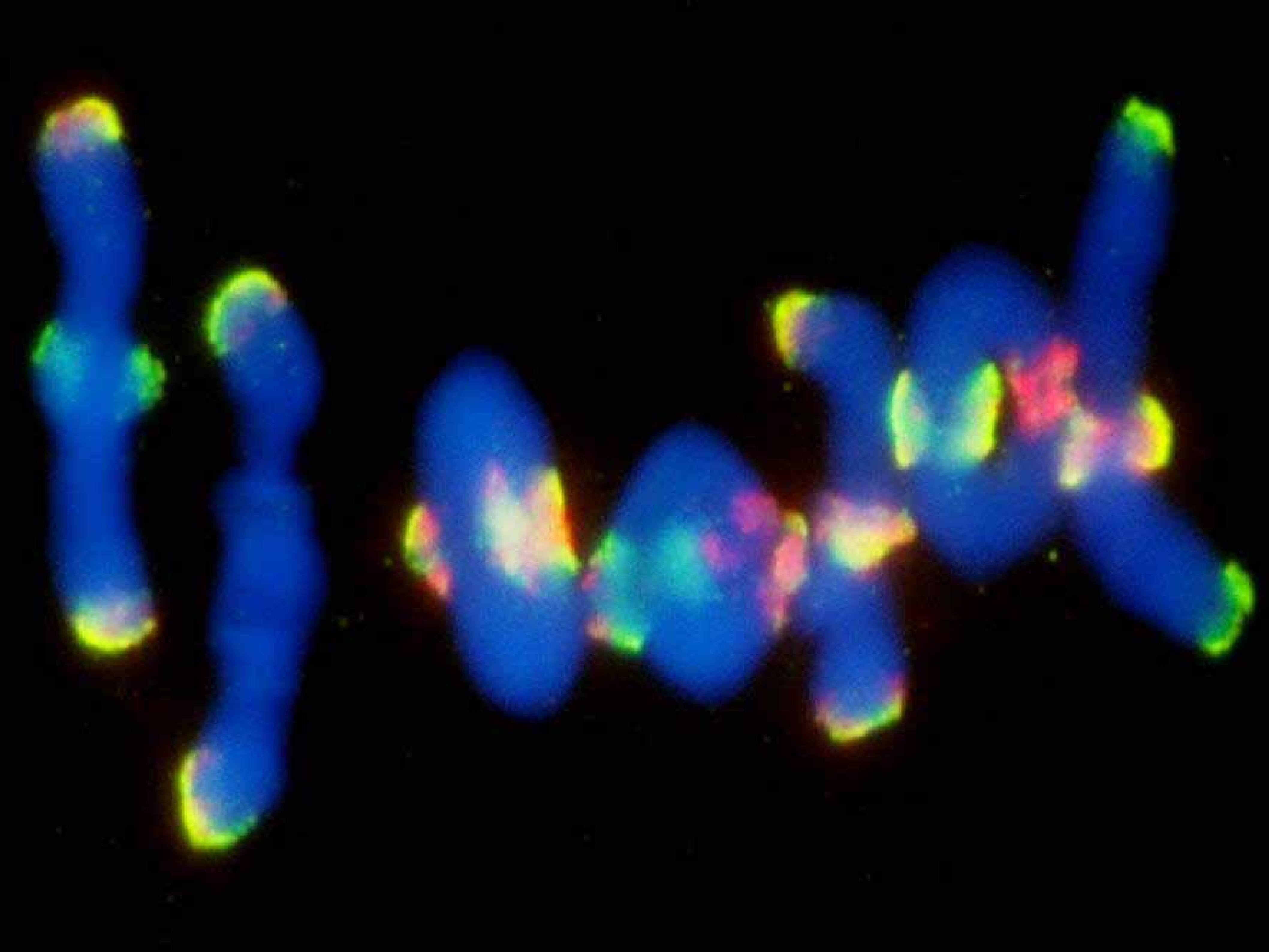
	Ploidy	2005	Genome size/Mbp
People		6,451,058,790	3300
Sugar Cane	10x (4-12x)	1,293,220,050	3000 (10x)
Maize	4x (palaeo)	692,034,184	2700
Wheat	6x	626,466,585	17000
Rice, Paddy	2x	614,654,895	440
Potatoes	4x	321,974,152	850
Sugar Beets	2x	241,985,317	760
Soybeans	4x	209,531,558	1100
Cassava	2x	203,863,208	770
Oil Palm Fruit	2x	173,261,199	1700
Barley	2x	138,267,192	5500
Sweet Potatoes	6x	129,888,827	
Tomatoes	2x	124,748,292	600
Bananas+plantains	3x	105,872,483	550
Citrus Fruit,Total	Var.	105,431,984	

	75% of food (calorie) consumption
People	
Sugar Cane	Stem
Maize	
Wheat	Seed endosperm
Rice, Paddy	
Potatoes	Tuber (modified leaf)
Sugar Beets	Root
Soybeans	Cotyledons
Cassava	Root
Oil Palm Fruit	Mesocarp around seed
Barley	Seed endosperm
Sweet Potatoes	Tuber
Tomatoes	Fruit
Bananas+plantains	Parthenocarpic fruit
Citrus Fruit,Total	Fruit

Also forage grasses and vegetables (leaves, flowers)

	Propagation
People	
Sugar Cane	Stem
Maize	F1 seed
Wheat	Seed
Rice, Paddy	Seed
Potatoes	Tuber
Sugar Beets	Seed
Soybeans	Seed
Cassava	Root
Oil Palm Fruit	F1 seed
Barley	Seed
Sweet Potatoes	Tuber
Tomatoes	F1 seed
Bananas+plantains	Sucker
Citrus Fruit,Total	Cuttings


THE HISTORY OF THE EARTH
IS RECORDED IN THE LAYERS OF ITS CRUST
THE HISTORY OF ALL ORGANISMS
IS INSCRIBED IN THE CHROMOSOMES
地球の歴史は地層に
生物の歴史は染色体に記されてある。
1946
Hitoshi Kihara, 1950
横浜市立大学
木原生物学研究所開所記念



Evolution of Wheats - Polyploidy

Common Ancestral Species
2n=2x=14

Triticum tauschii
2n=2x=14
DD

Aegilops uniaristata
2n=2x=14
NN

Aegilops ventricosa
2n=4x=28
DDNN

Genes are only a small part of the DNA

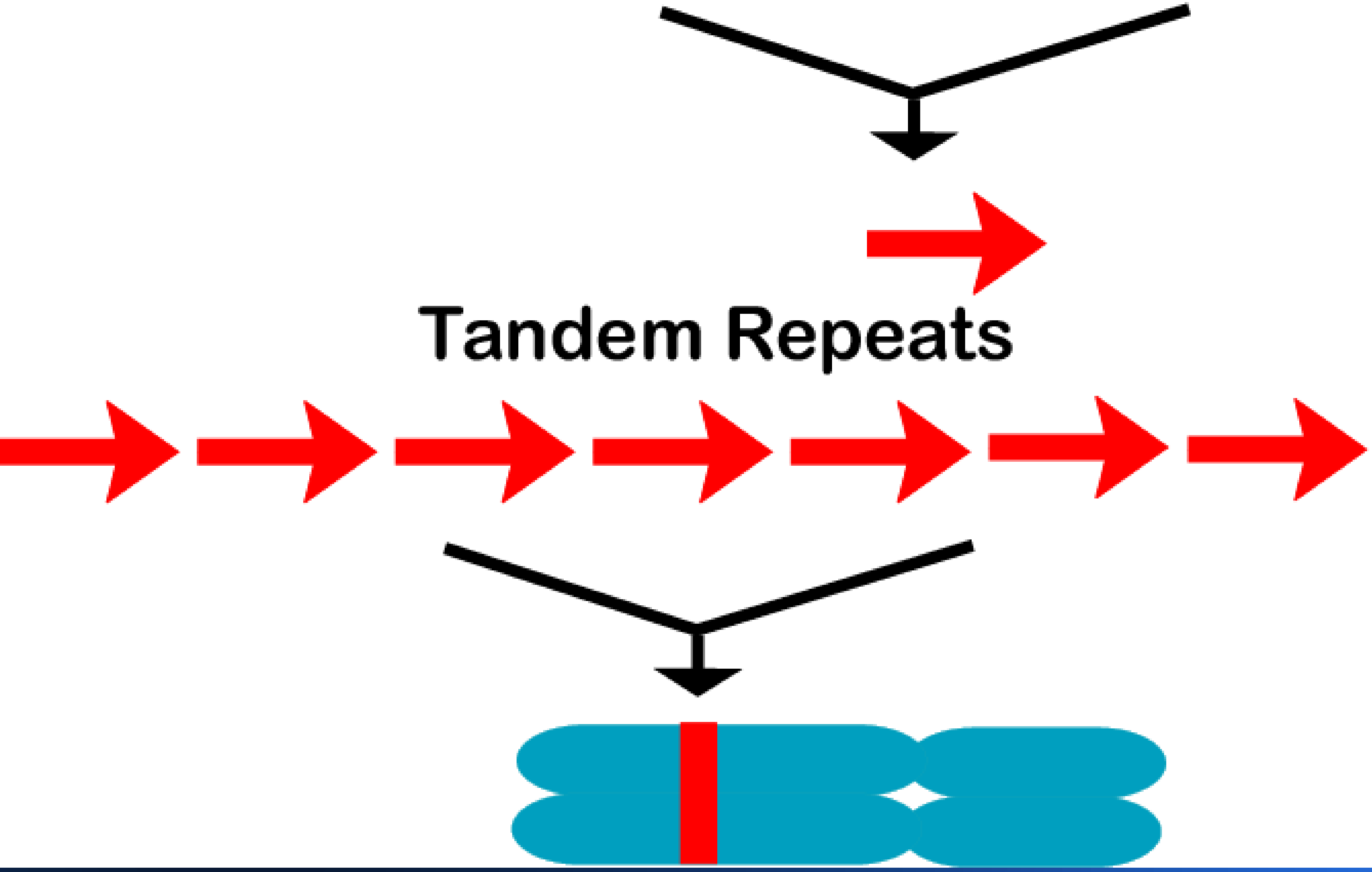
The rest of the genome is made up of repeated DNA motifs from 2 to several thousand base pairs long

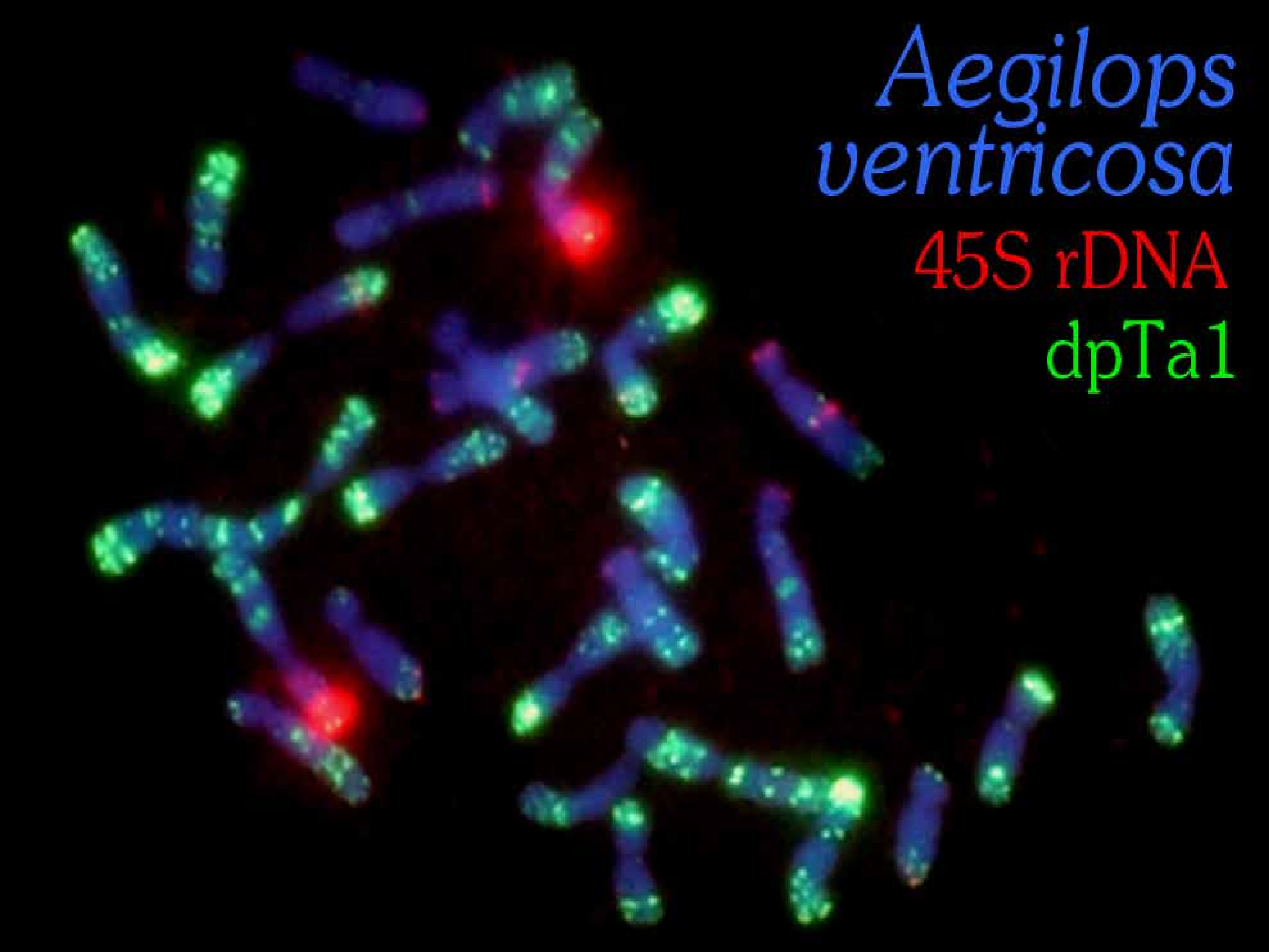
The Repetitive DNA is often rapidly evolving

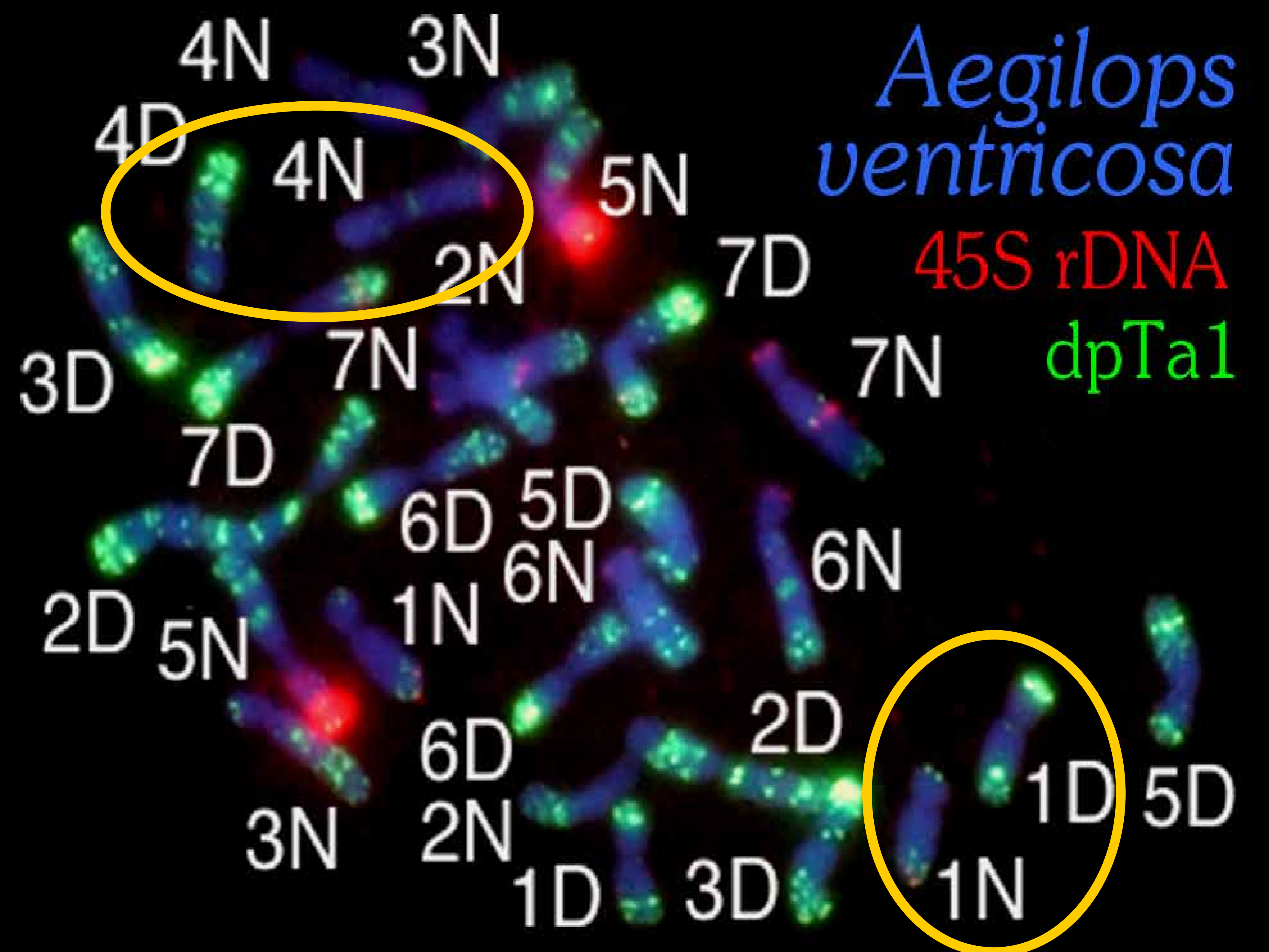
It includes repeated genes (rDNA)
Tandemly repeated, non-coding DNA

Tandemly arranged DNA monomers

Repeat monomer: CCTAGCGTAACGGTACGGCTAGC

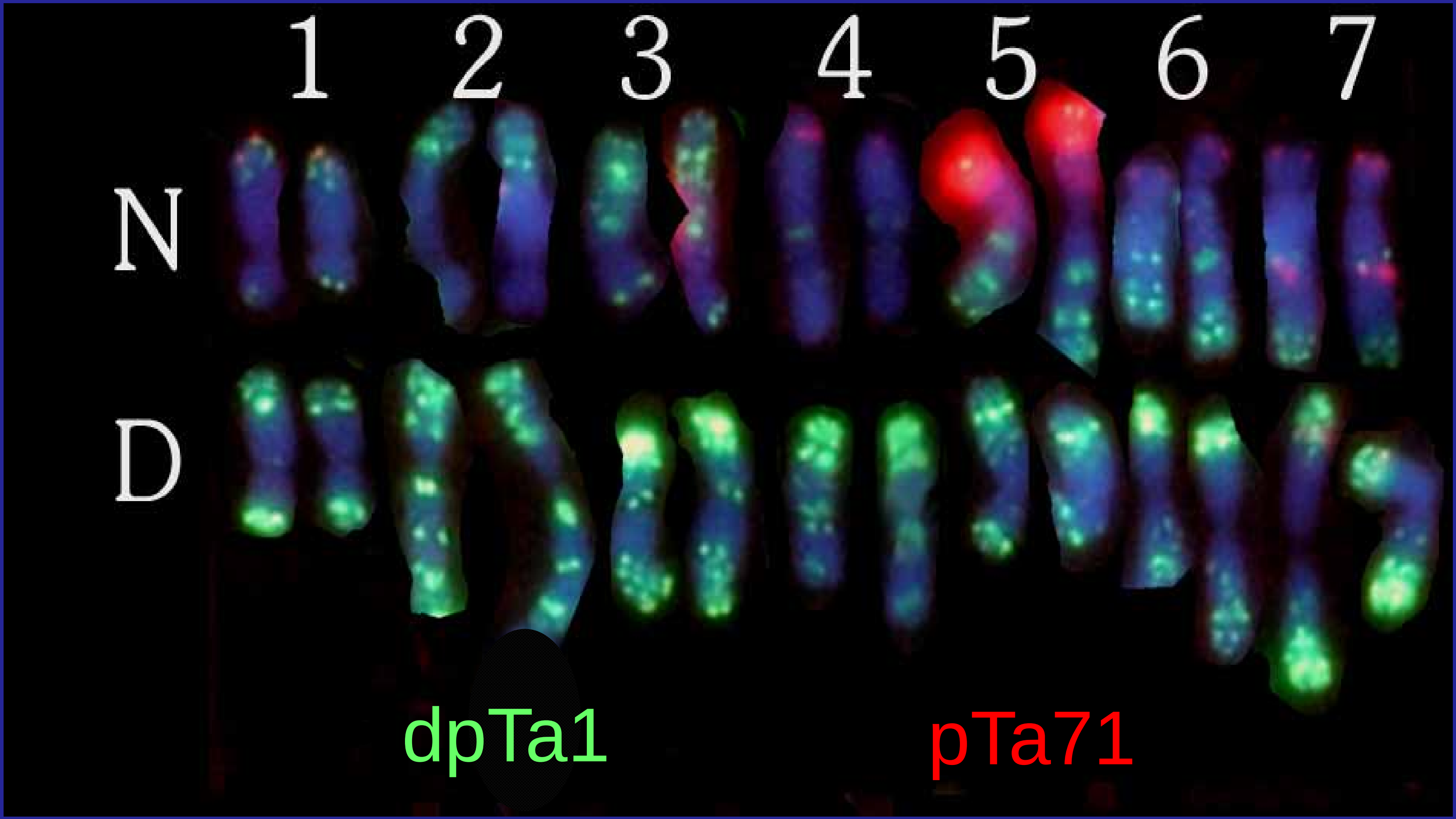



Aegilops
ventricosa
45S rDNA
dpTa1

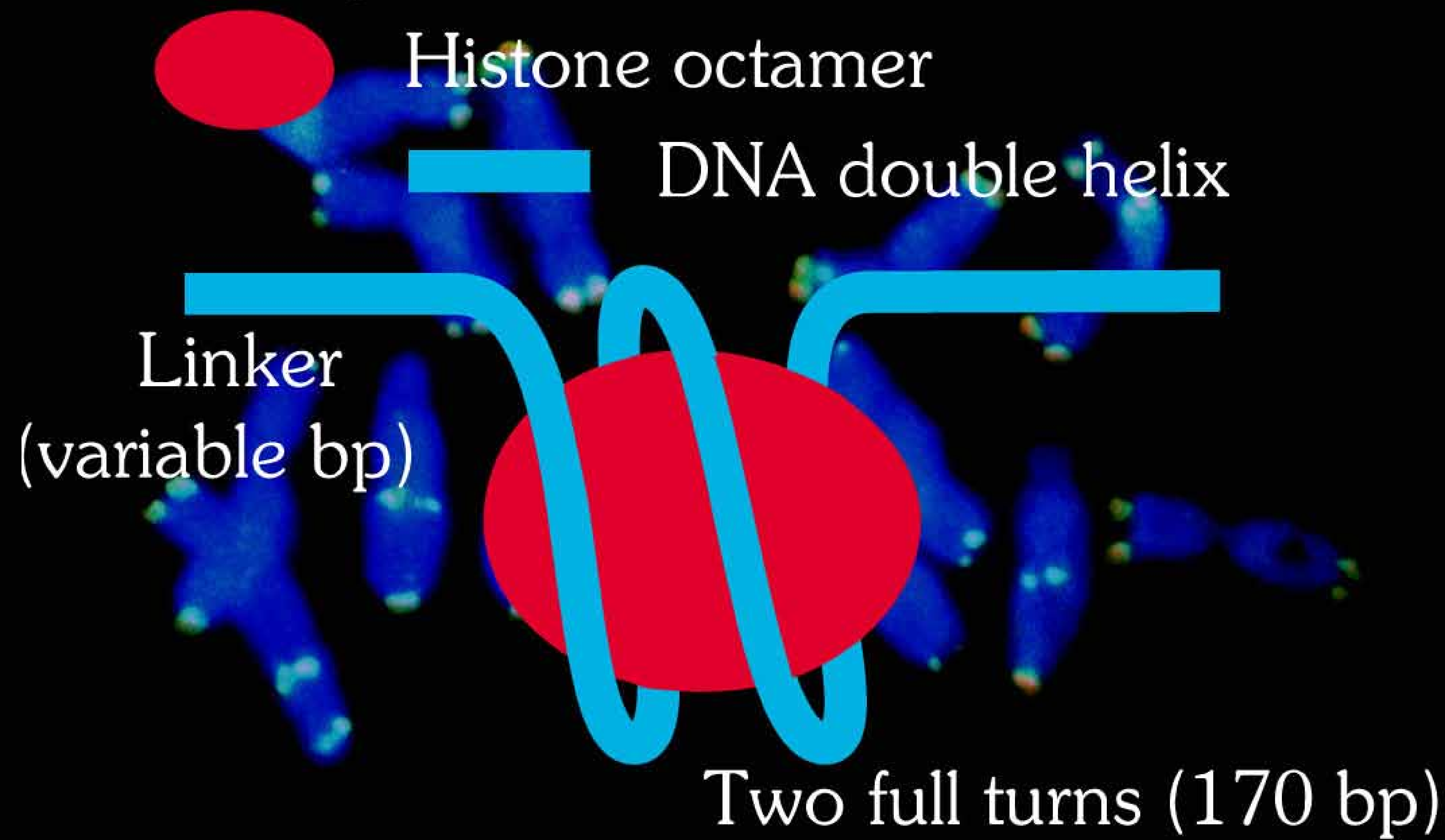

Aegilops ventricosa
45S rDNA
dpTa1
4N
3N
4D
4N
5N
2N
7D
3D
7N
7N
7D
6D
5D
6N
6N
2D
5N
1N
6D
2D
1D
5D
3N
2N
1D
3D
1N

Differences between genomes

Major differences in the nature and amount of repetitive DNA

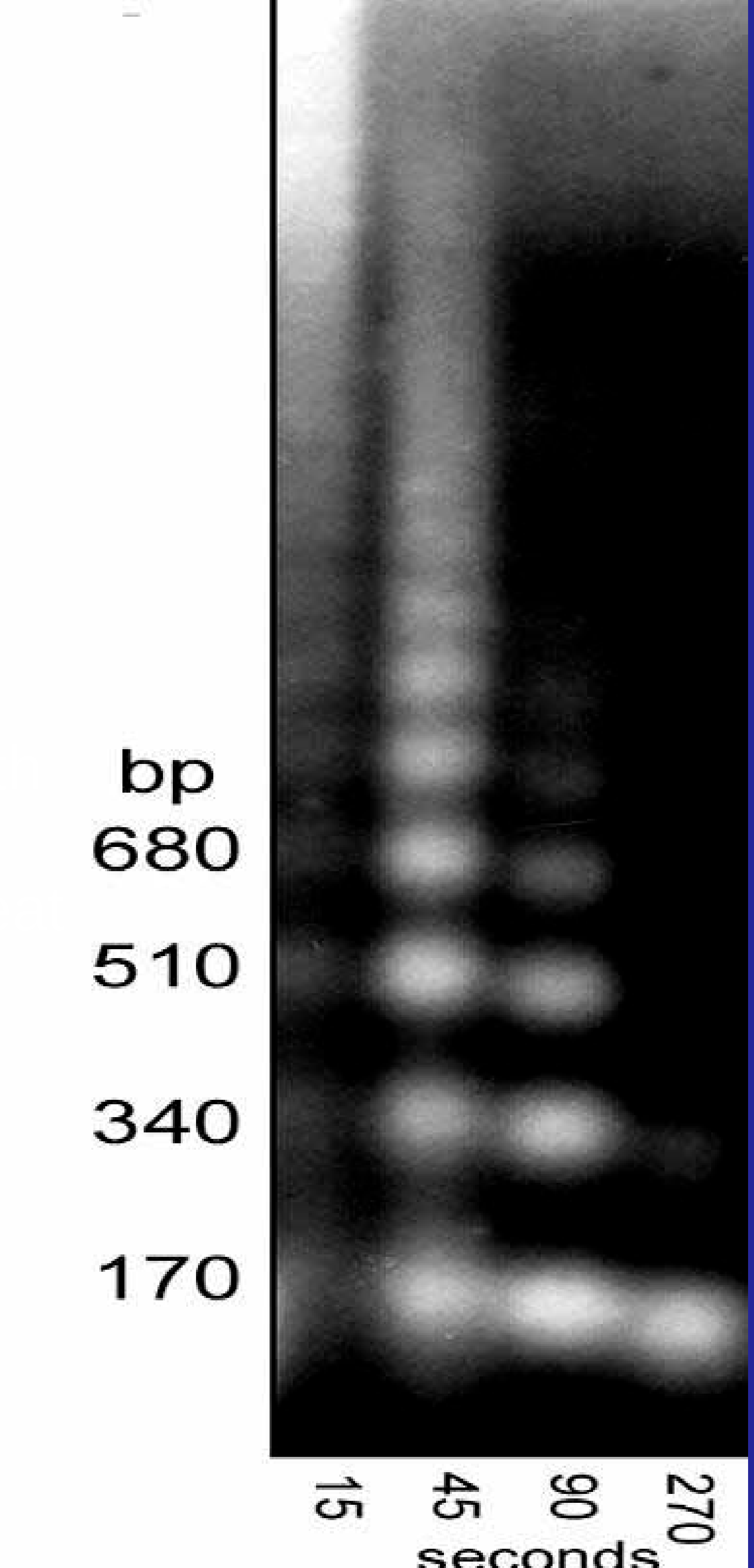


DNA packs around nucleosomes



Nucleosomes in Rye

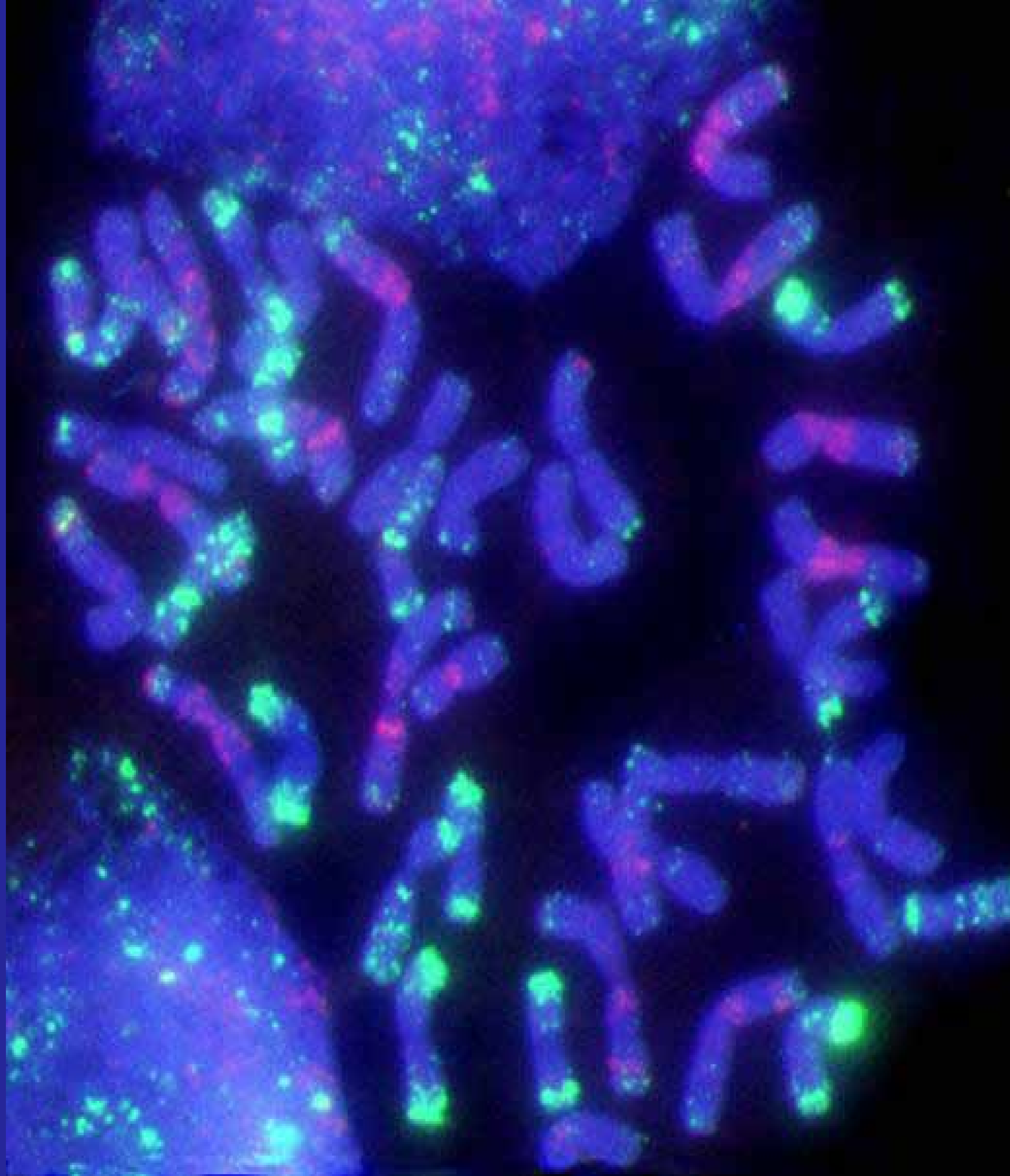
Digest intact chromatin (DNA + histone) wit
micrococcal nuclease for a few seconds,
cutting between the nucleosomes. Then tre
with protease and run on agarose gel.



Vershinin &

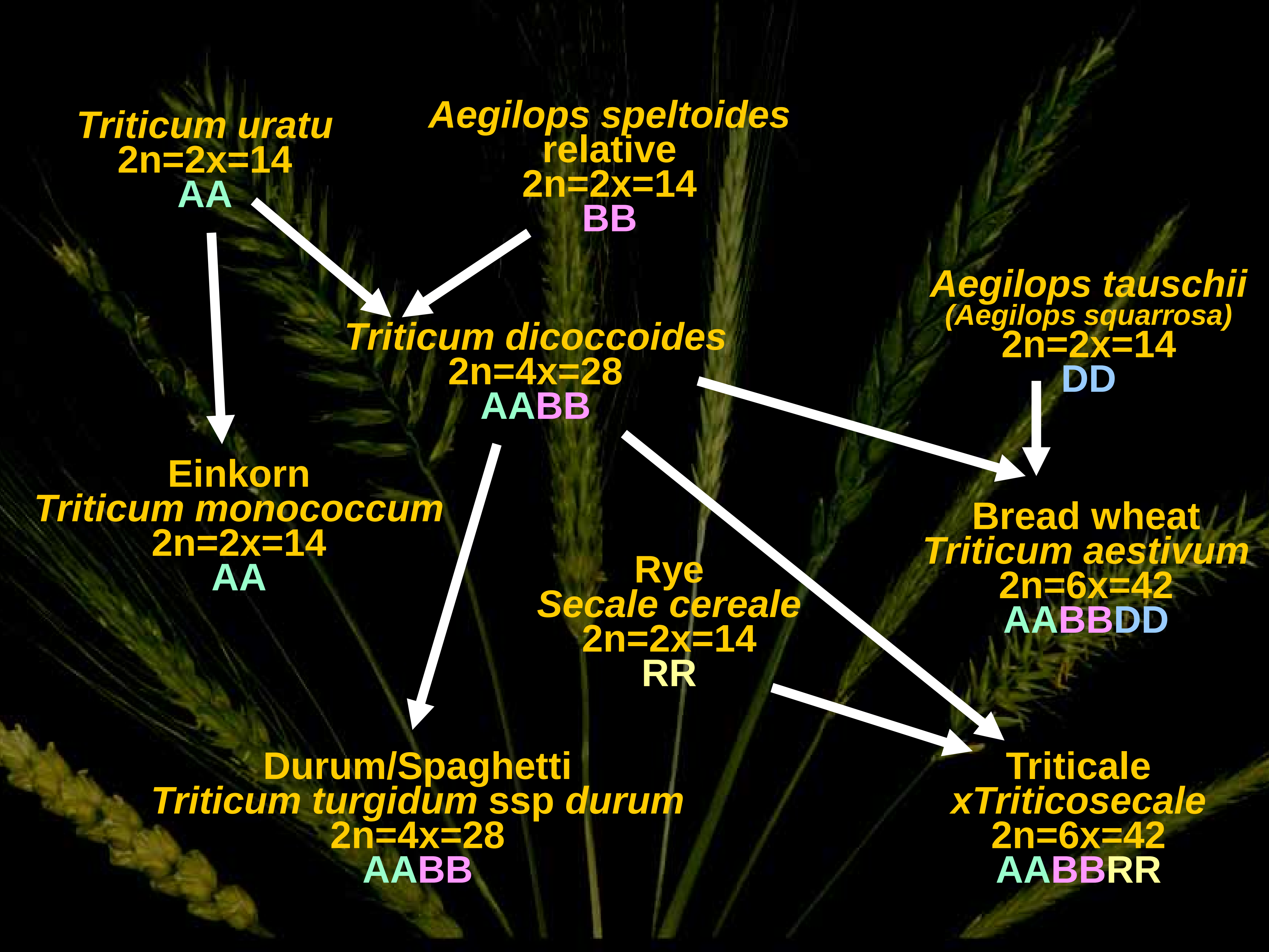
Heslop-Harrison

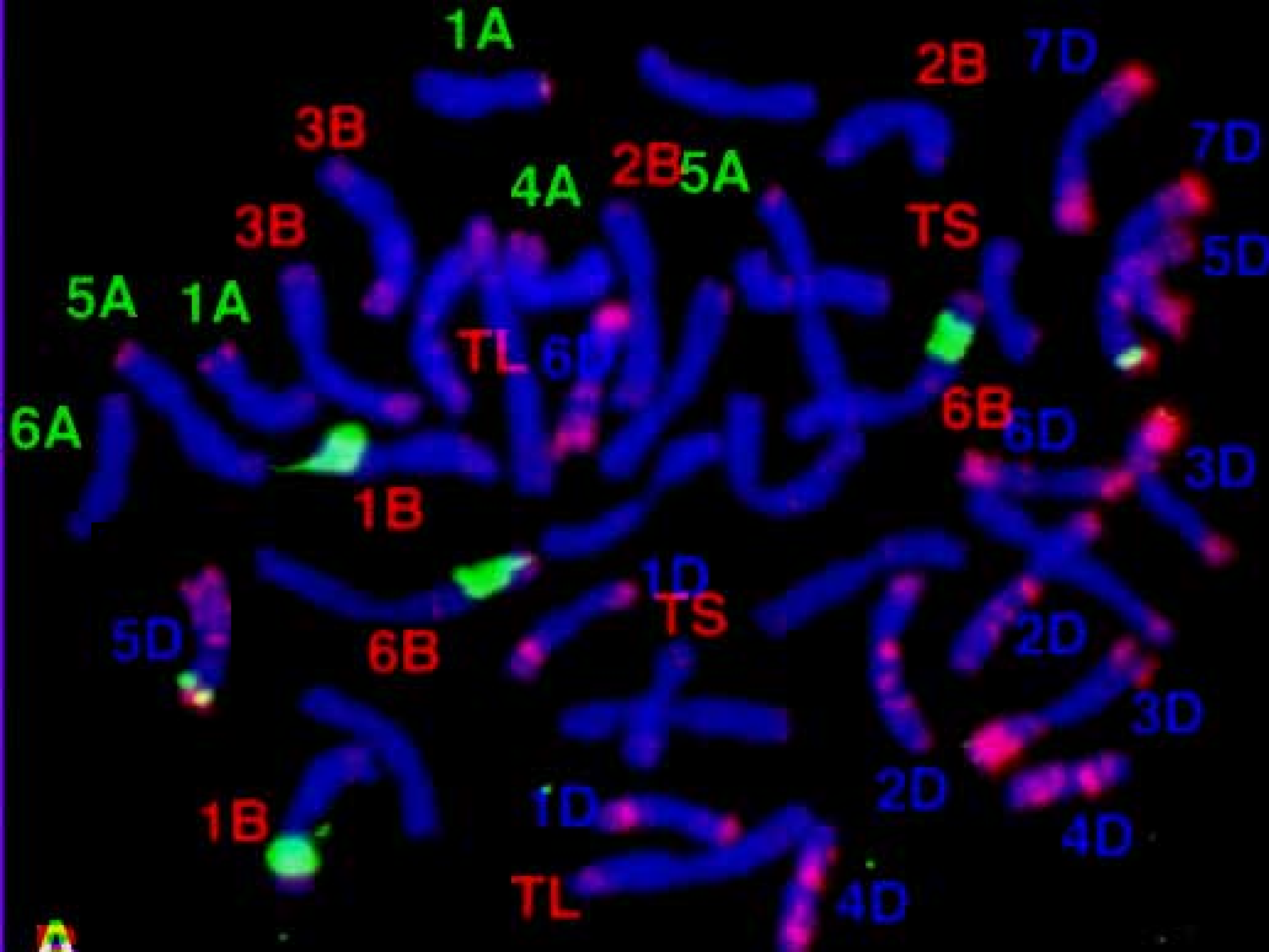

Lodging in cereals
UK July 2007

Eyespot (fungus *Pseudocercosporella*) resistance from *Aegilops ventricosa* introduced to wheat by chromosome engineering

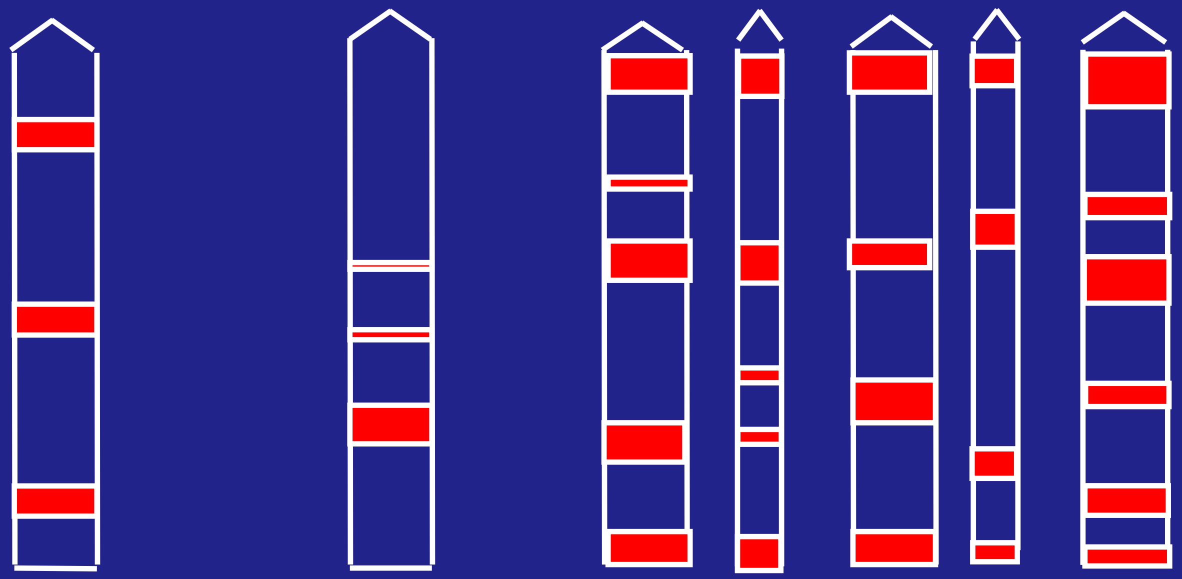
Many diseases where *all* wheat varieties are highly susceptible


Triticum uratu
2n=2x=14
AA
Aegilops speltoides relative
2n=2x=14
BB
Triticum dicoccoides
2n=4x=28
AABB
Aegilops tauschii
(Aegilops squarrosa)
2n=2x=14
DD
Einkorn
Triticum monococcum
2n=2x=14
AA
Rye
Secale cereale
2n=2x=14
RR
Bread wheat
Triticum aestivum
2n=6x=42
AABBDD
Durum/Spaghetti
Triticum turgidum ssp *durum*
2n=4x=28
AABB
Triticale
xTriticosecale
2n=6x=42
AABBRR


1A
2B
7D
3B
2B
5A
4A
TS
7D
3B
5D
5A
1A
TL
6D
6B
6D
6A
3D
1B
1D
TS
5D
6B
2D
3D
2D
1B
1D
4D
TL
4D

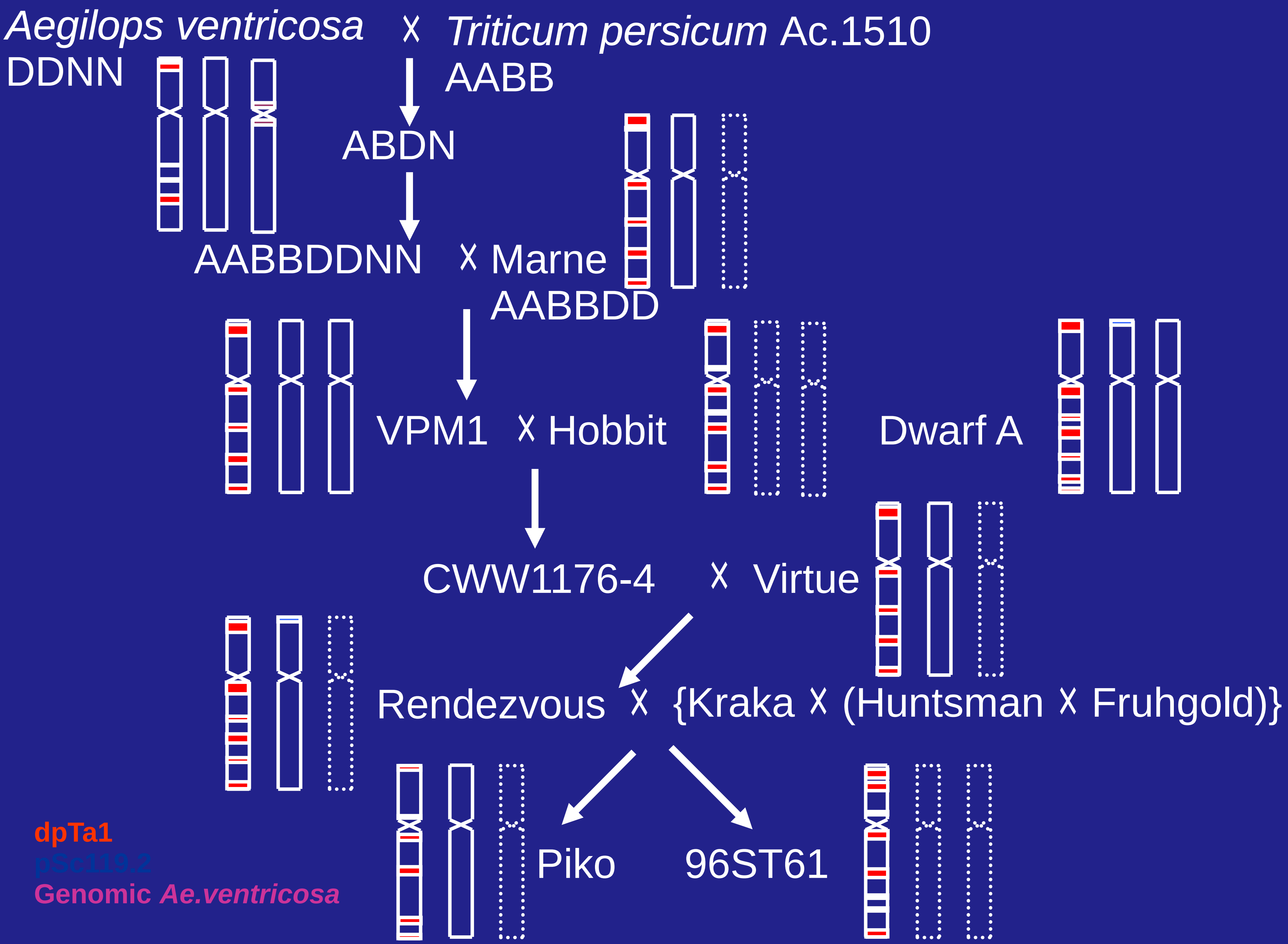
Multiple repeat (dpTa1) variants of each chromosome

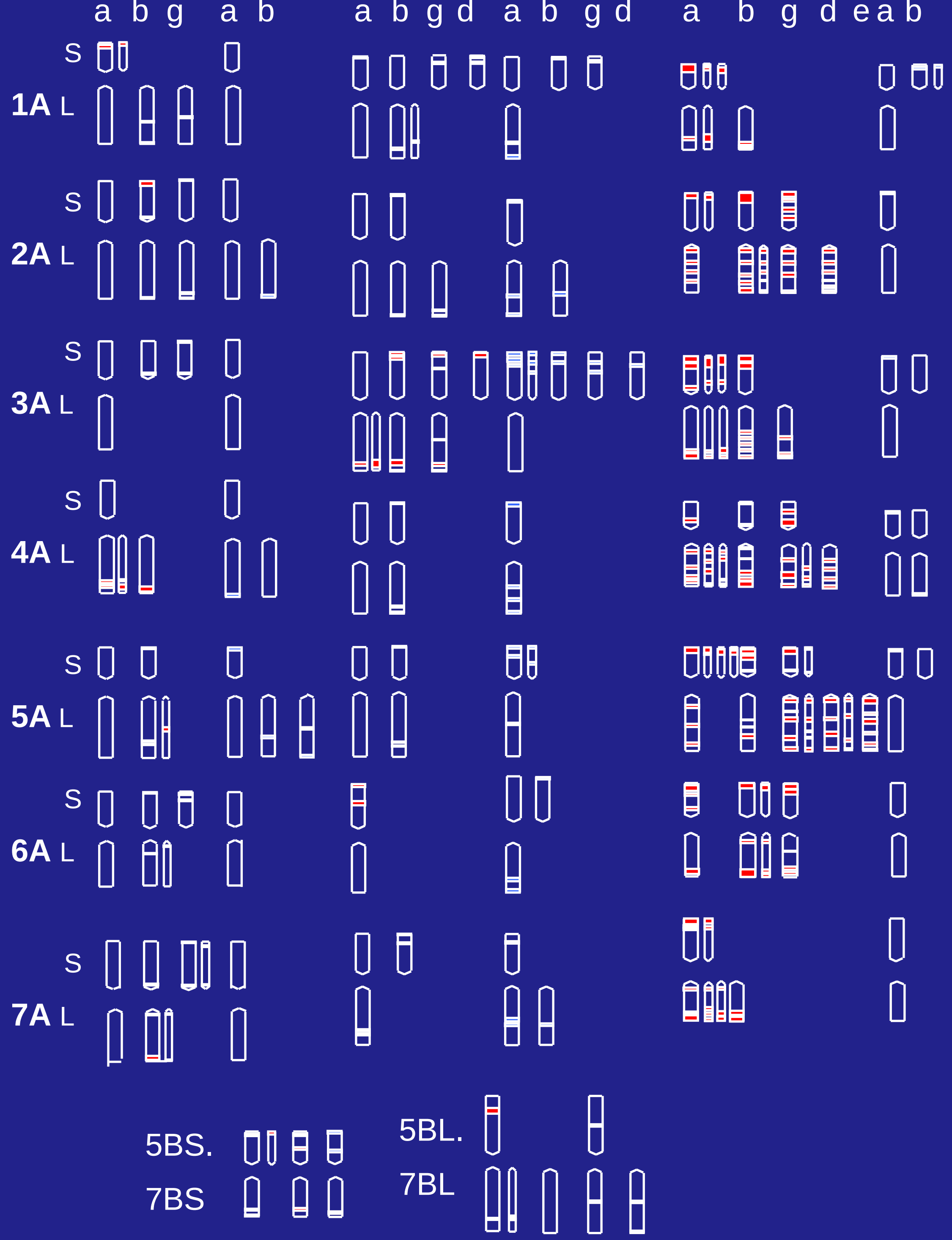
e.g. 5DL



Bardsley, Schwarzacher & HH

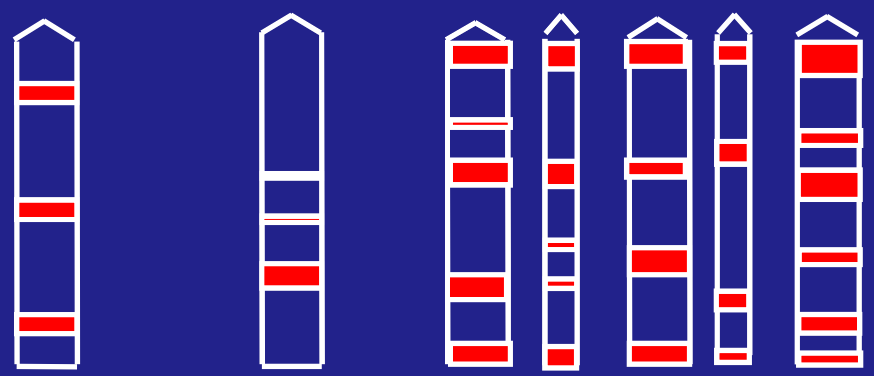
Inheritance of Chromosome 5D





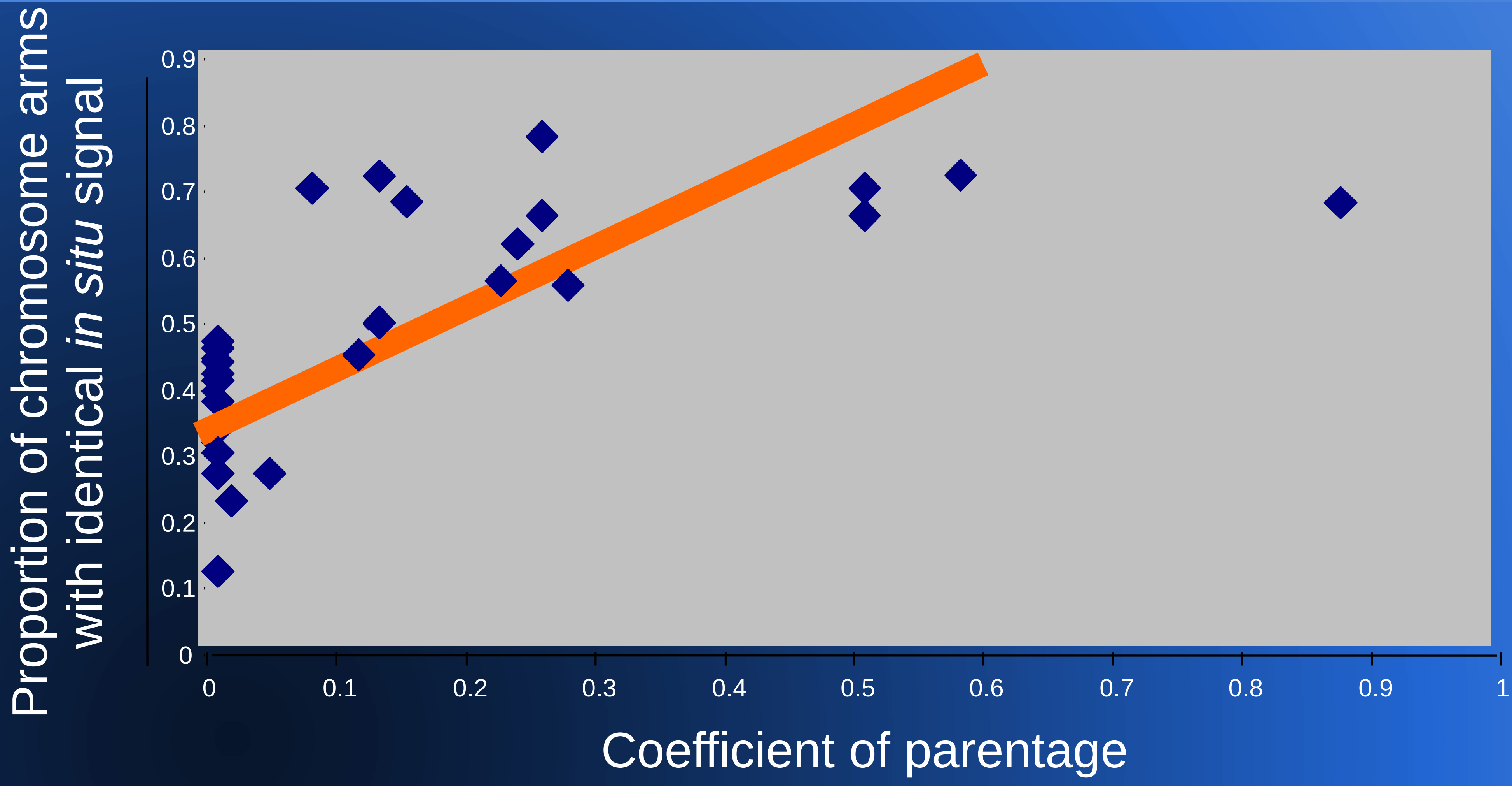
Multiple dpTa1 variants of each chromosome

e.g. 5DL

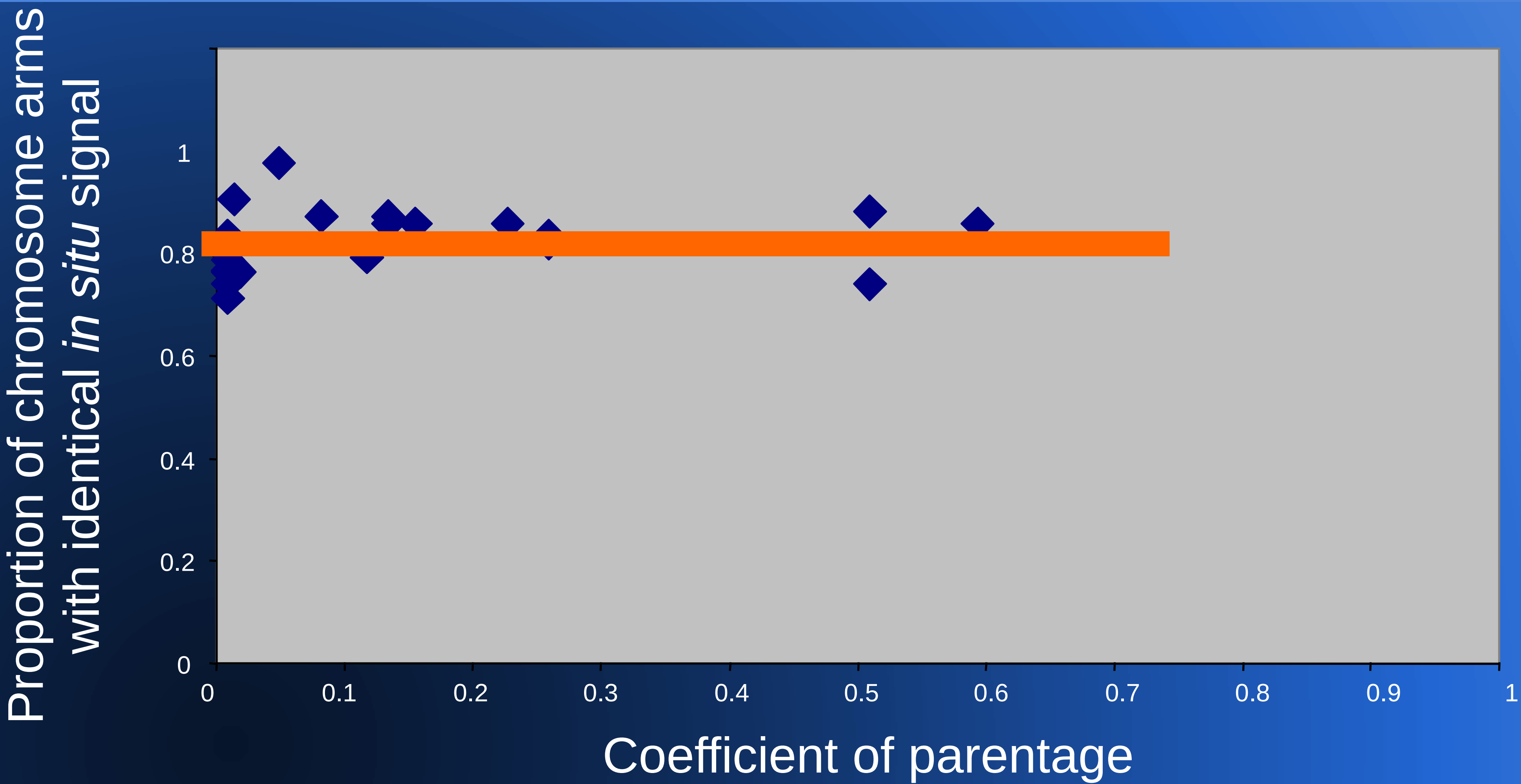


Bardsley, Schwarzacher & HH

Correlation between genetic relationships and similarity of dpTa1 hybridization



No correction between genetic relationships and similarity of pSc119.2 hybridization

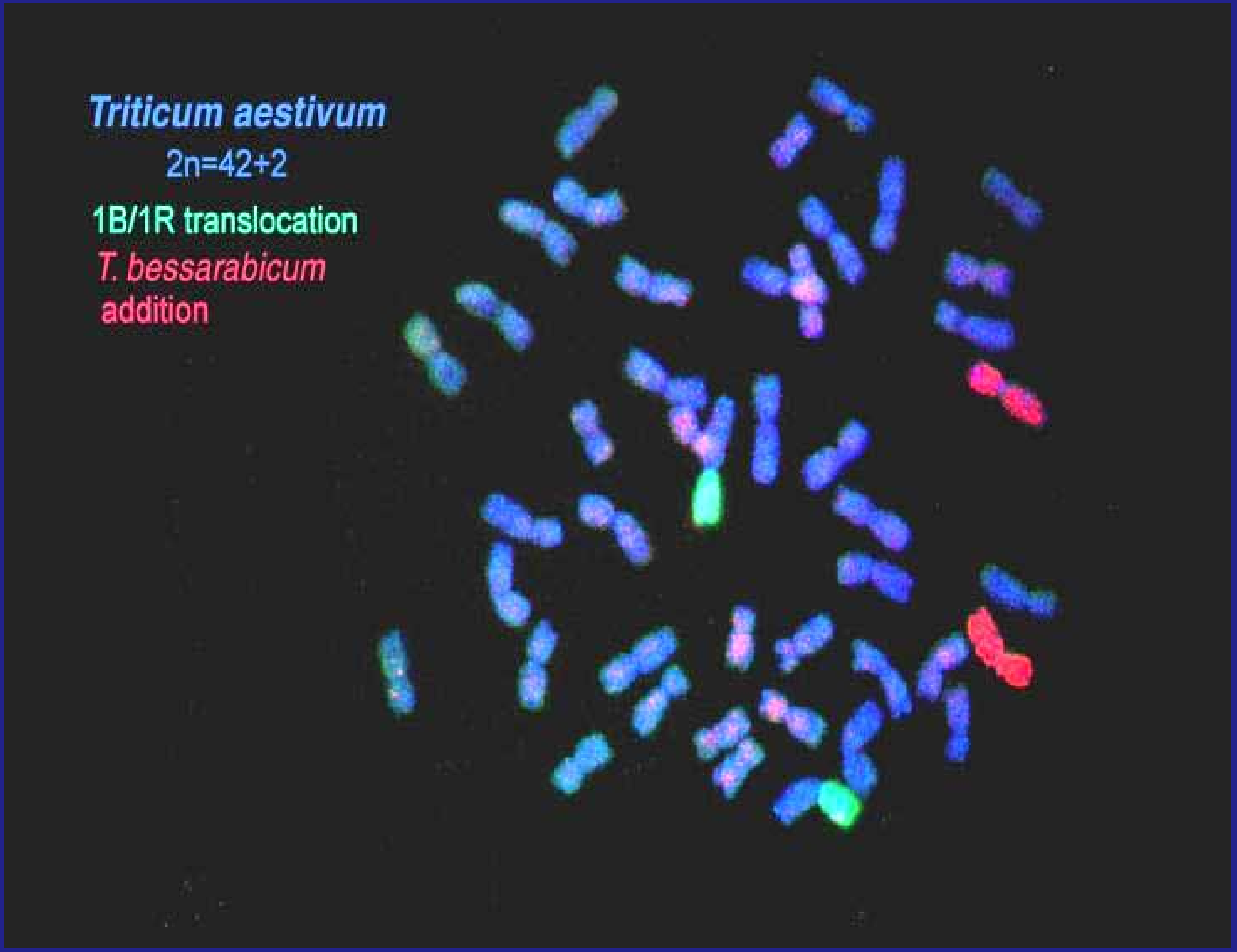


Evolution and Diversity

- Different classes of sequence behave differently
  - Evolve at different rates
  - Have different selective pressures
  - Vary in mechanism of evolution
- Sequences are used as markers
  - Linked to selectable genes

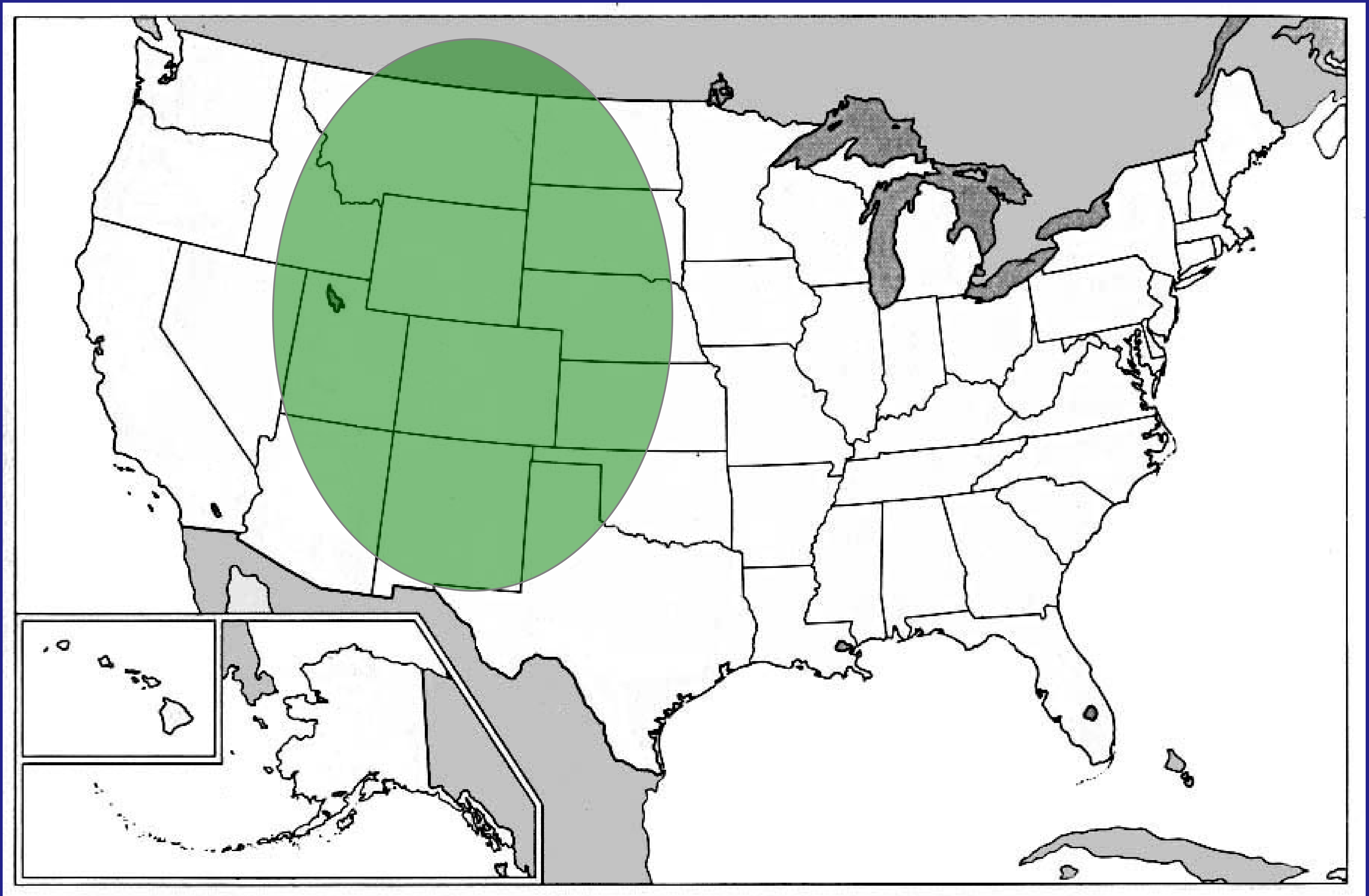
Total genomic DNA can be used as a probe to distinguish

- Genomes in sexual hybrids
- Alien chromosome introgression

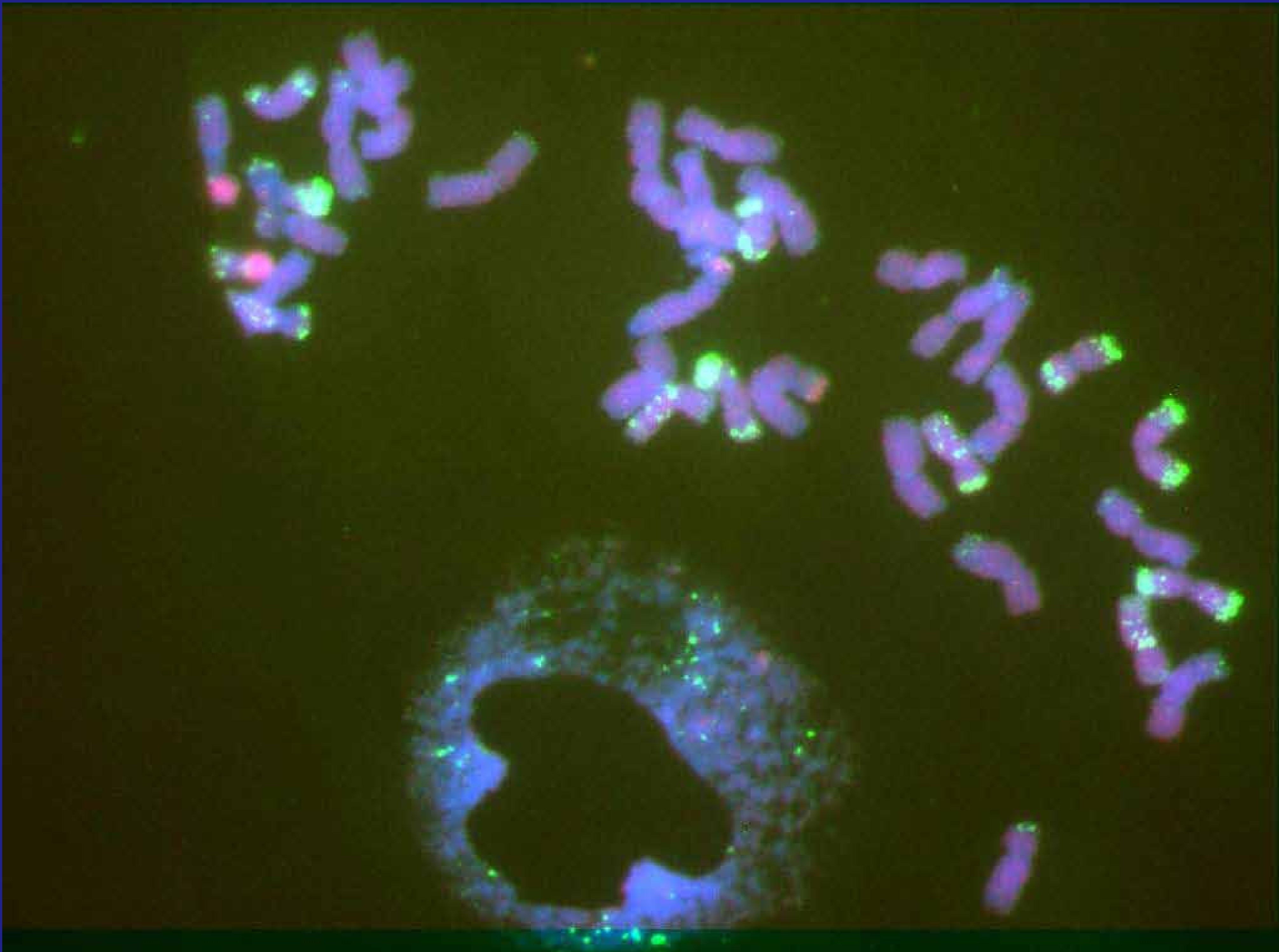


Mace wheat
Graybosch et al. 2009
In situ: Niaz Ali & Schwarzacher

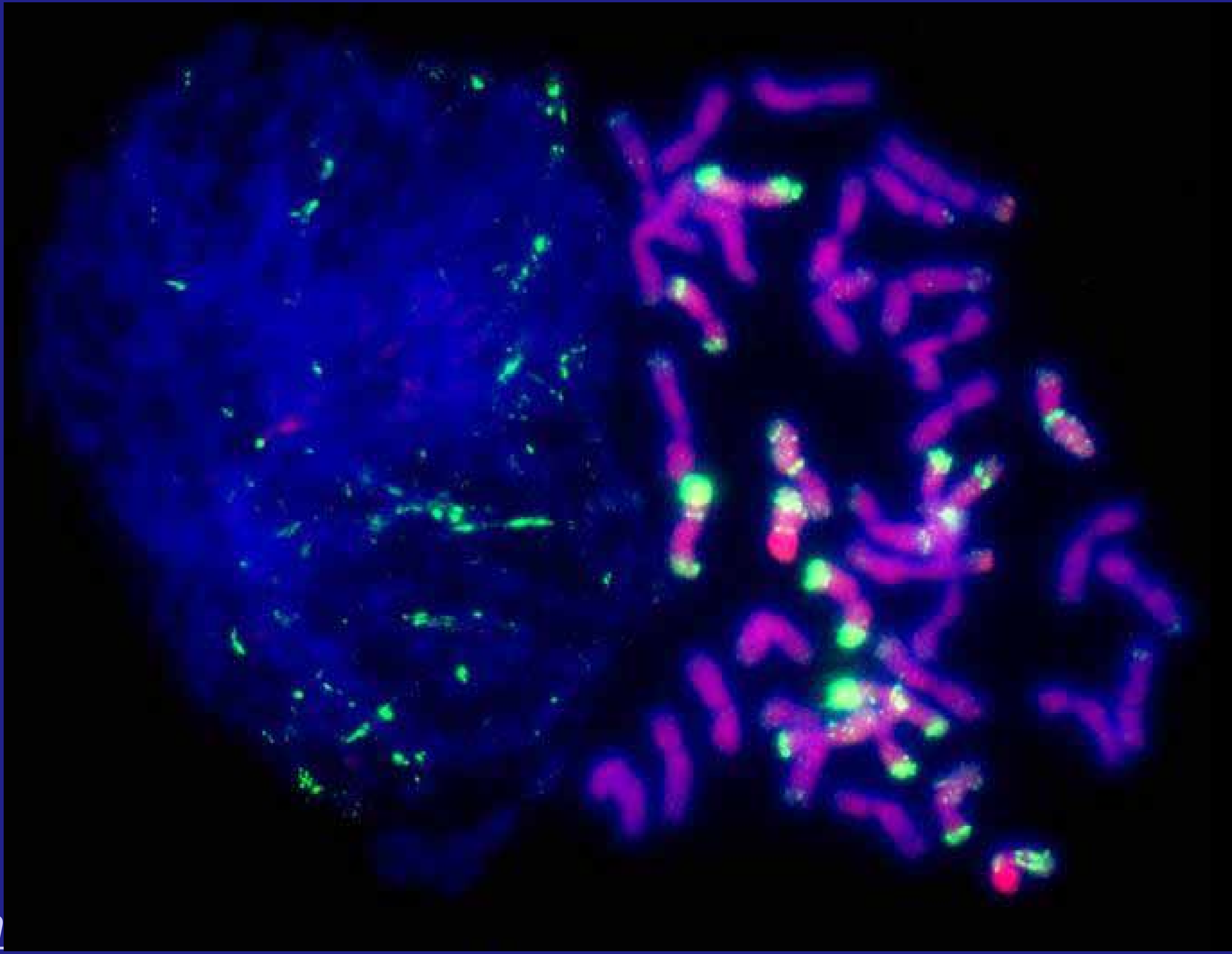
Wheat Streak Mosaic Virus in North America
Bob Graybosch, USDA



Wsm-1: only highly effective source of resistance to WSMV



Wsm1 Resistance Gene



cated on a small insert of chromatin m Agropyron intermedium (Horst.) auv. (=*Thinopyrum intermedium) on eat chromosome 4A or 4D.*

- *What chromosome arm is present in our advanced breeding lines.*
- *Can we develop procedures to rapidly screen & characterize hundreds of germplasm lines?*

obes

- *IWG genomic DNA – biotin*
- *dpTA1 (D-genome specific) digoxigenin*

aybosch et al. 2009. Registration Mace hard red winter wheat. urnal of Plant Registrations

Registration of 'Mace' Hard Red Winter Wheat

R. A. Graybosch,* C. J. Peterson, P. S. Baenziger, D. D. Baltensperger, L. A. Nelson, Y. Jin, J. Kolmer, B. Seabourn, R. French, G. Hein, T. J. Martin, B. Beecher, T. Schwarzacher, and P. Heslop-Harrison

ABSTRACT

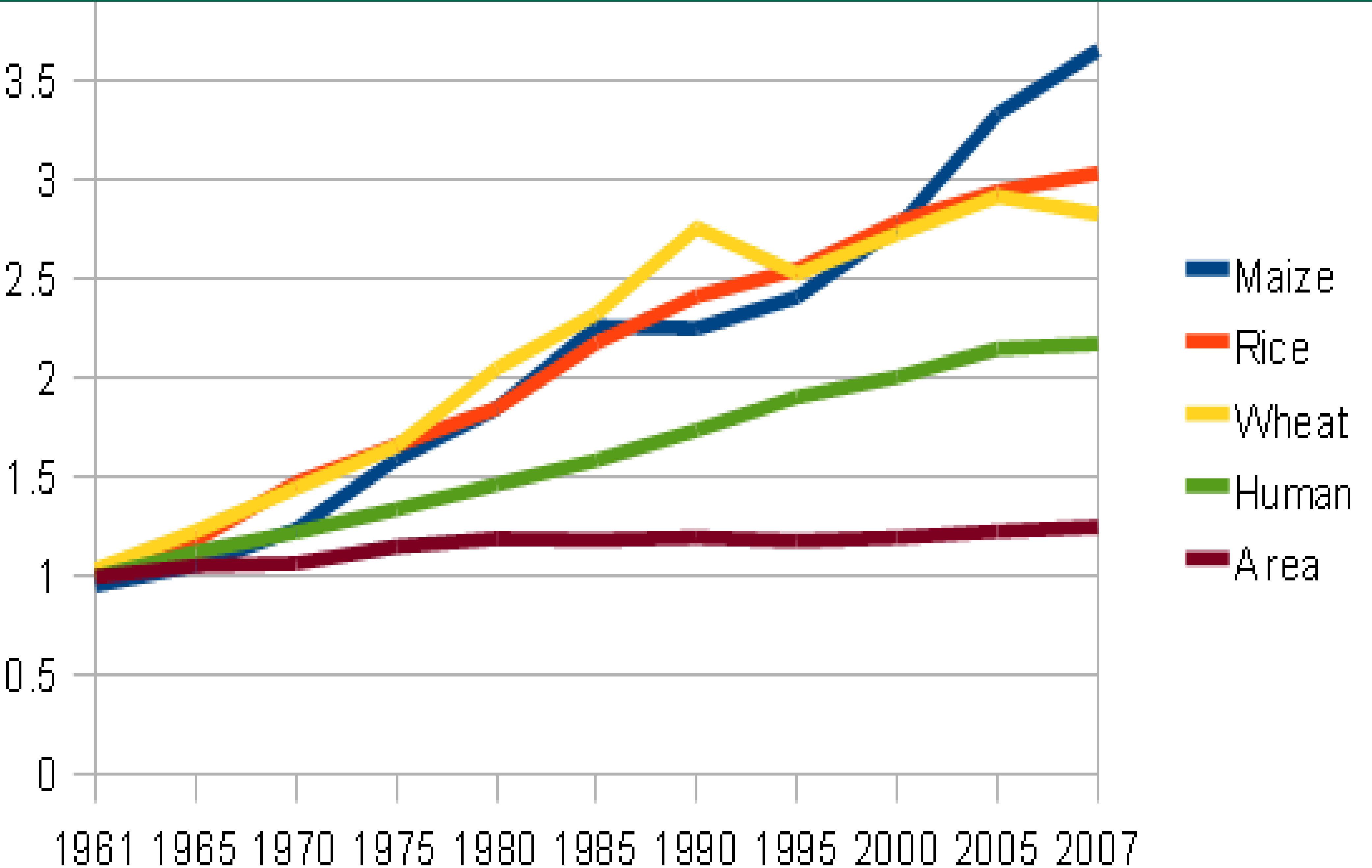
'Mace' (Reg. No. CV-1027, PI 651043) hard red winter wheat (*Triticum aestivum* L.) was developed by the USDA-ARS and the Nebraska Agricultural Experiment Station and released in December 2007. Mace was selected from the cross Yuma//PI 372129/3/CO850034/4/4*Yuma/5/(KS91H184/Arlin S//KS91HW29/3/NE89526). Mace primarily was released for its resistance to *Wheat streak mosaic virus* (WSMV) and adaptation to rainfed and irrigated wheat production systems in Nebraska and adjacent areas in the northern Great Plains. Mace was derived from a head selection made from a heterogeneous, in terms of field resistance to WSMV, F_5 line. Resistance to WSMV is conditioned by the *Wsm-1* gene, located on an introgressed chromosome arm from *Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey [*Agropyron intermedium* (Horst.) Beauv.] present as a 4DL.4AgS chromosomal translocation. Mace was tested under the experimental designation N02Y5117.

Abbreviations: NRPN, Northern Regional Performance Nursery; PCR, polymerase chain reaction; WSBMV, *Wheat soilborne mosaic virus*; WSMV, *Wheat streak mosaic virus*.

Published in the Journal of Plant Registrations 3:51–56 (2009).
doi: 10.3198/jpr2008.06.0345crc

such line, subsequently named 'Mace' (Reg. No. CV-1027, PI 651043), was deemed suitable for cultivar release. Mace is a hard red winter wheat cultivar developed cooperatively by the USDA-ARS and the Nebraska Agricultural Experiment Station and released in 2007 by the developing institutions. Mace was released primarily for its field resistance to *Wheat streak mosaic virus* (WSMV) and adaptation to rainfed and irrigated wheat production systems in Nebraska and adjacent areas in the northern Great Plains. Resistance to WSMV is conditioned by the *Wsm-1* gene (Seifers et al., 1995), situated on an introgressed chromosome arm from

Cereal Production 1961-2007



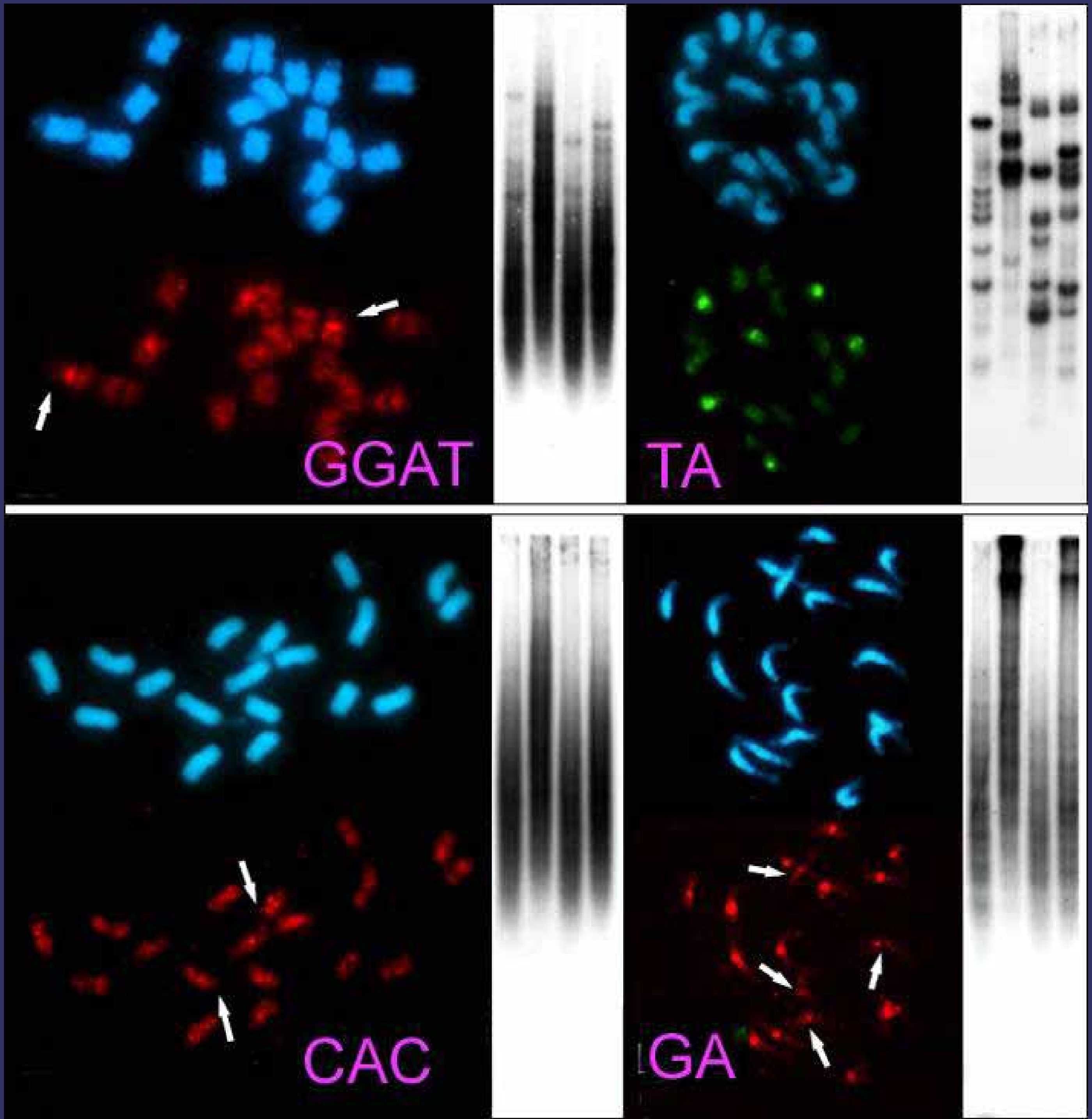
Genes are only a small part of the DNA

The rest of the genome is made up of repeated DNA motifs from 2 to several thousand base pairs long

The Repetitive DNA is often rapidly evolving

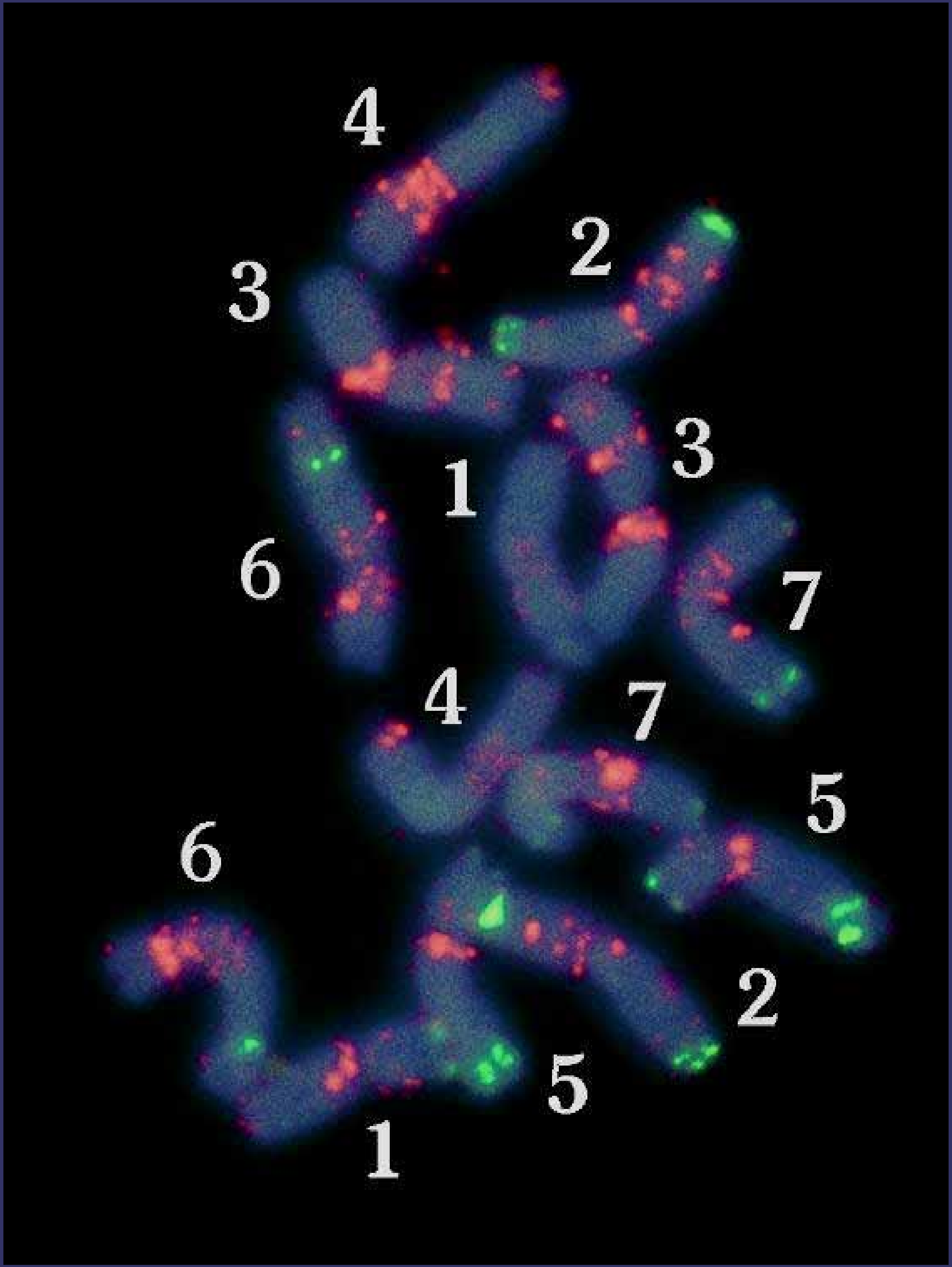
It includes repeated genes (rDNA)
Tandemly repeated, non-coding DNA

Simple Sequence Repeats



Sugar beet: Characteristic organization of each motif

Schmidt, HH et a



Rye
Secale cereale
2n=14

DAPI

FITC/Alexa 488

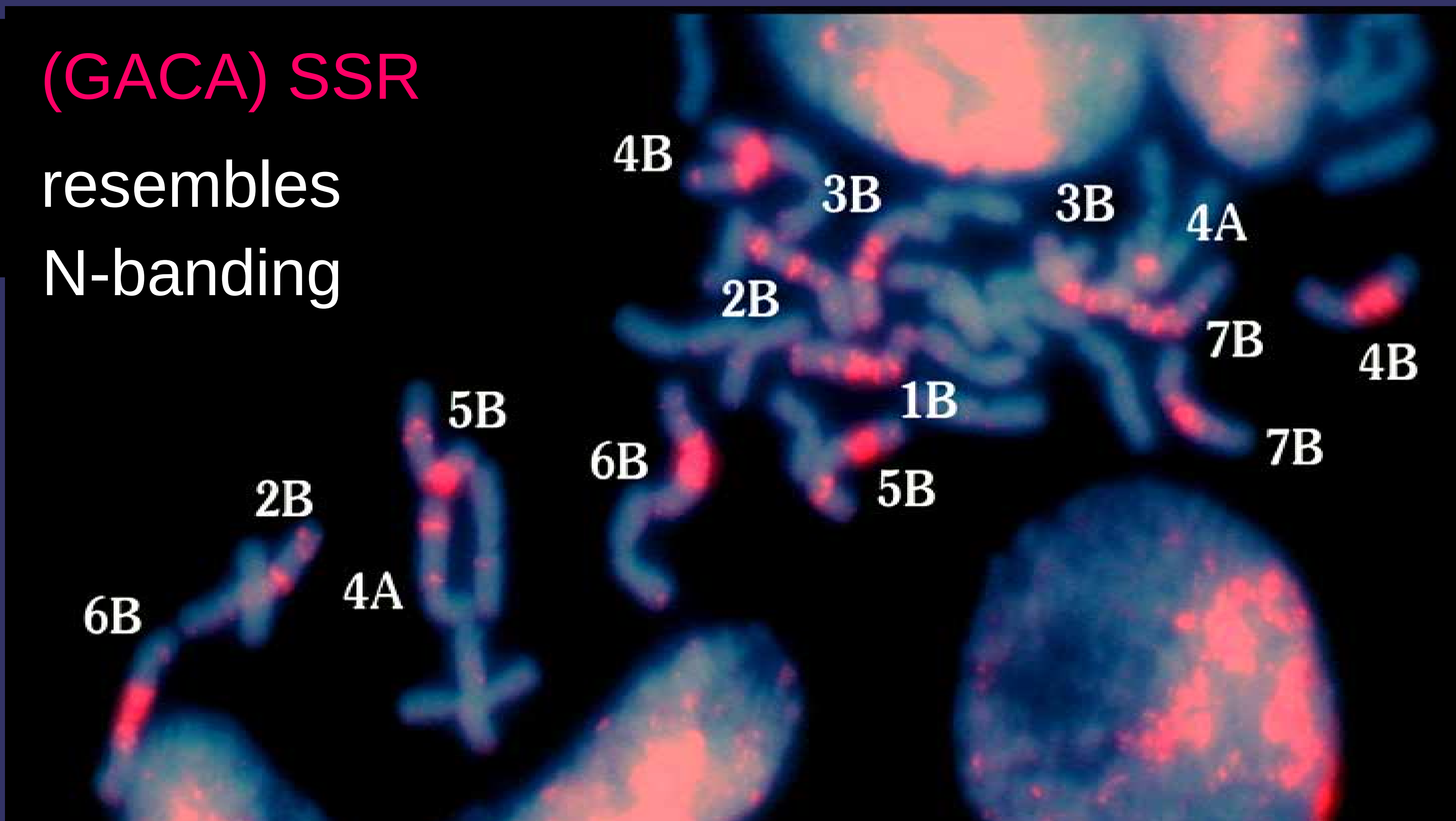
Cy3/Alexa 594

Wheat ‘Chinese Spring’

(GACA) SSR

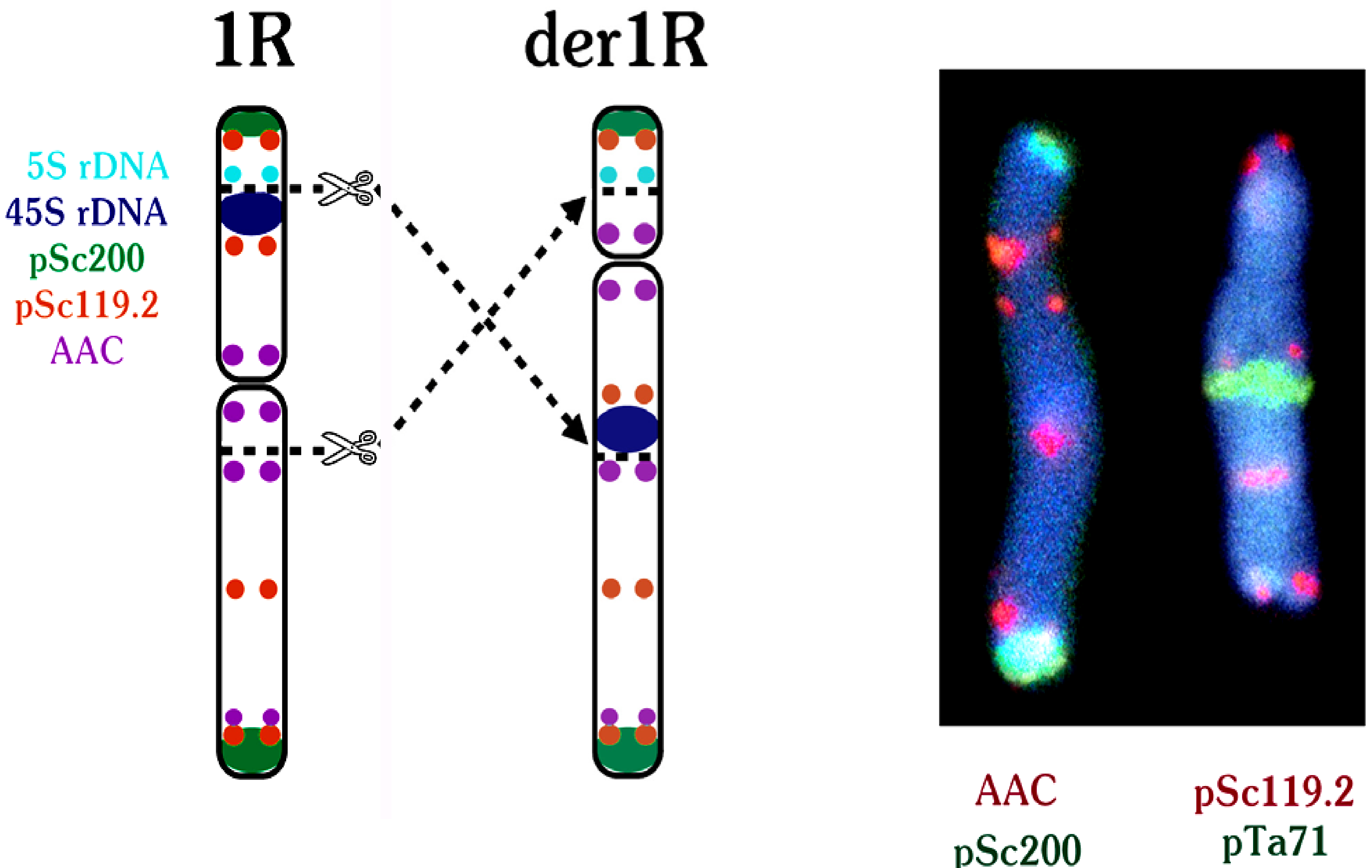
resembles

N-banding



Cuadrado and Schwarzacher 1998

Derivative chromosome 1R of Lines 7-102 and 7-169



Forsstrom and Schwarzacher 2000


Iran – coast from over Persian Gulf – Feb 2007

Aegilops tauschii (D genome donor) in Iran

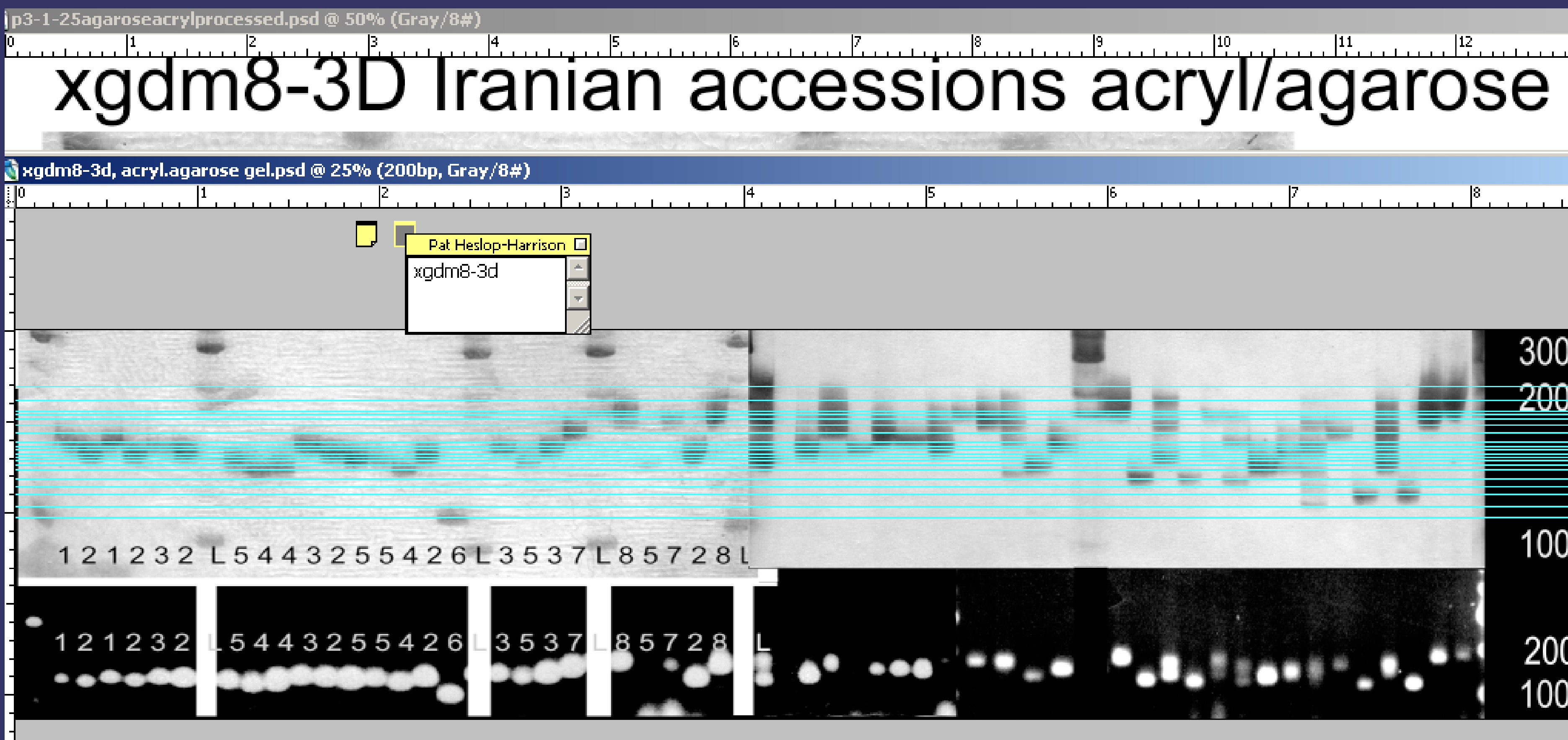
HOW MUCH DIVERSITY IS THERE?

57 accessions collected

- ssp. *tauschii*
  - *var. meyeri* (19)
  - *var. tauschii* (22)
  - *var. anathera* (4)
  - *var. strangulata* (12)
- Hexaploid wheat

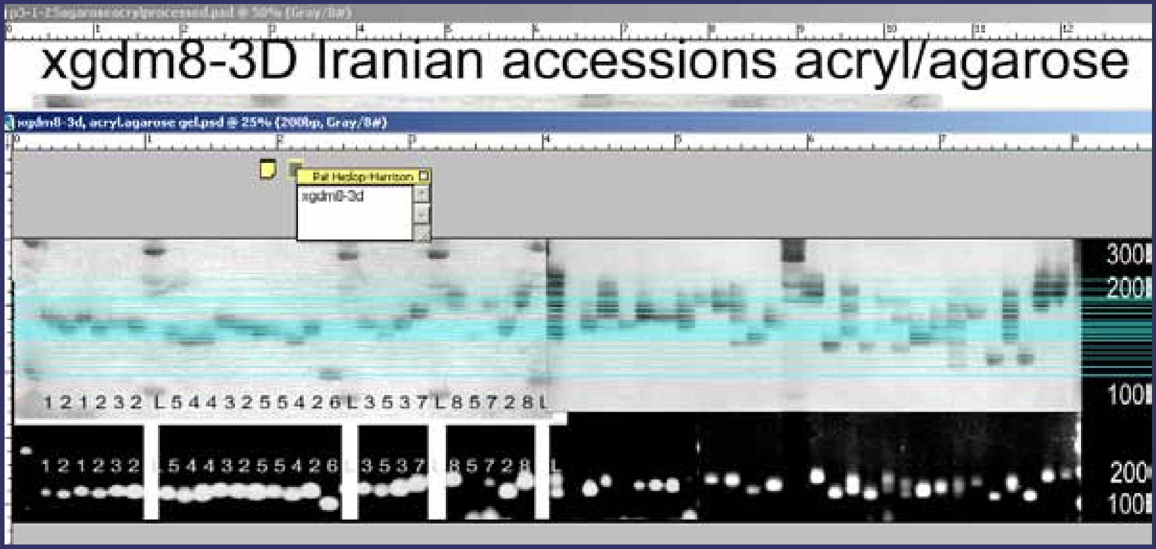
Hojjatollah Saeidi, Mohammad Reza Rahiminejad, Sadeq
Vallian, HH
Genetic Resources & Crop Plant Evolution 2006

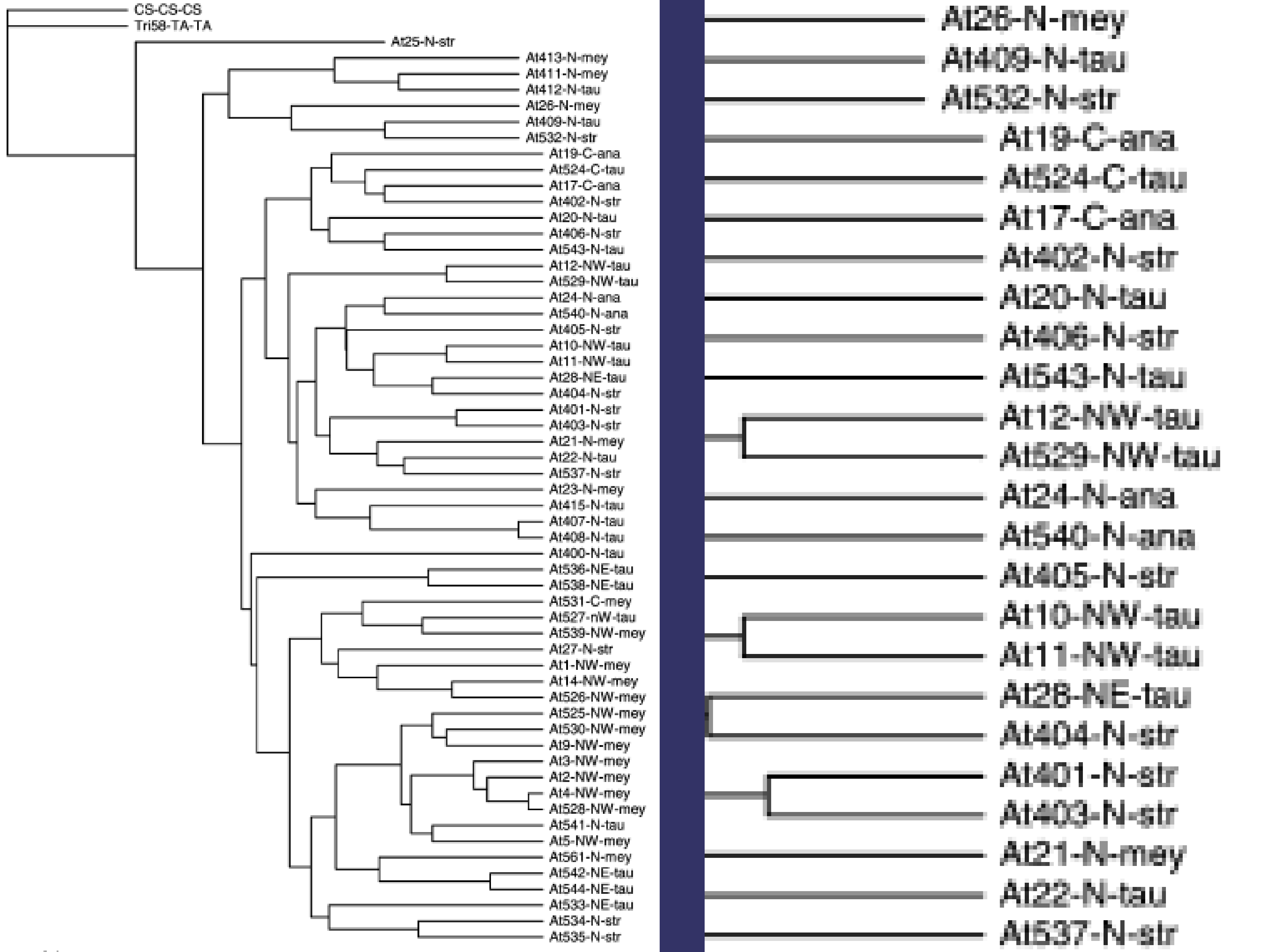
'SSRs' they all cried …
(microsatellites; PCR)



'SSRs' they all cried …

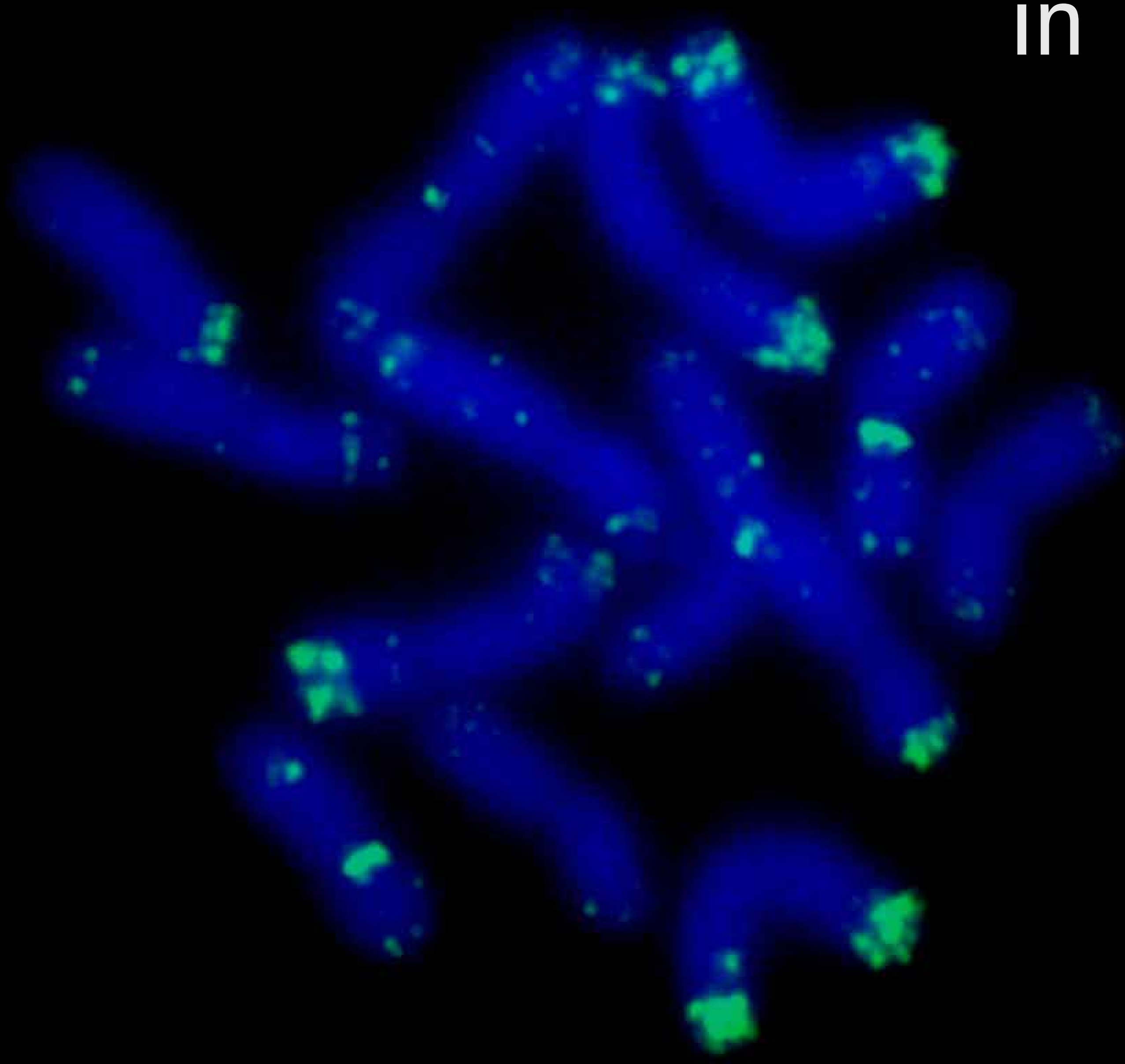
A few pairs of collections were rather similar
Everything else was different

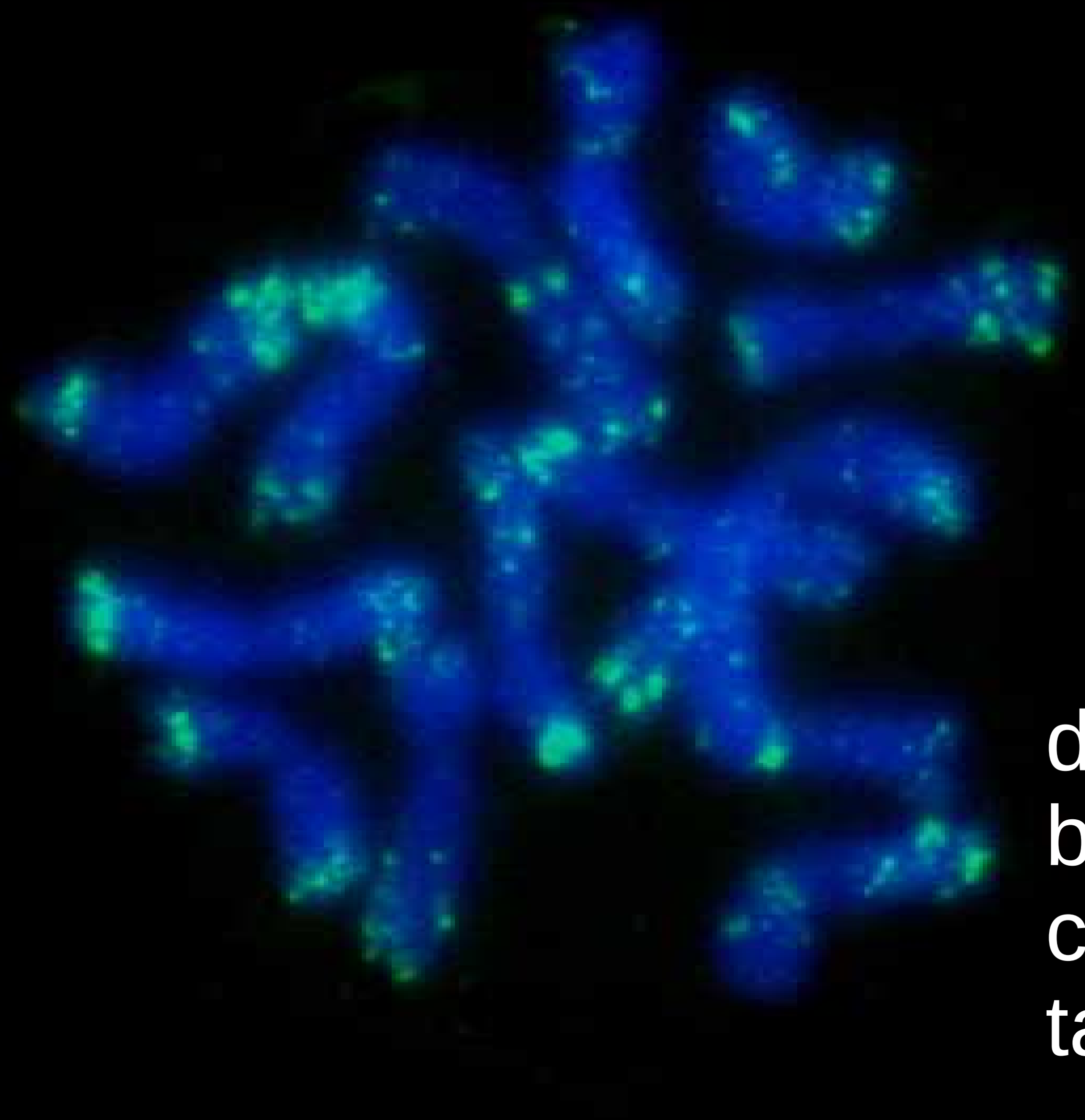



CS-CS-CS
Tri58-TA-TA
At25-N-str
At413-N-mey
At411-N-mey
At412-N-tau
At26-N-mey
At409-N-tau
At532-N-str
At19-C-ana
At524-C-tau
At17-C-ana
At402-N-str
At20-N-tau
At406-N-str
At543-N-tau
At12-NW-tau
At529-NW-tau
At24-N-ana
At540-N-ana
At405-N-str
At10-NW-tau
At11-NW-tau
At28-NE-tau
At404-N-str
At401-N-str
At403-N-str
At21-N-mey
At22-N-tau
At537-N-str
At23-N-mey
At415-N-tau
At407-N-tau
At408-N-tau
At400-N-tau
At536-NE-tau
At538-NE-tau
At531-C-mey
At527-nW-tau
At539-NW-mey
At27-N-str
At1-NW-mey
At14-NW-mey
At526-NW-mey
At525-NW-mey
At530-NW-mey
At9-NW-mey
At3-NW-mey
At2-NW-mey
At4-NW-mey
At528-NW-mey
At541-N-tau
At5-NW-mey
At561-N-mey
At542-NE-tau
At544-NE-tau
At533-NE-tau
At534-N-str
At535-N-str
At26-N-mey
At409-N-tau
At532-N-str
At19-C-ana
At524-C-tau
At17-C-ana
At402-N-str
At20-N-tau
At406-N-str
At543-N-tau
At12-NW-tau
At529-NW-tau
At24-N-ana
At540-N-ana
At405-N-str
At10-NW-tau
At11-NW-tau
At28-NE-tau
At404-N-str
At401-N-str
At403-N-str
At21-N-mey
At22-N-tau
At537-N-str

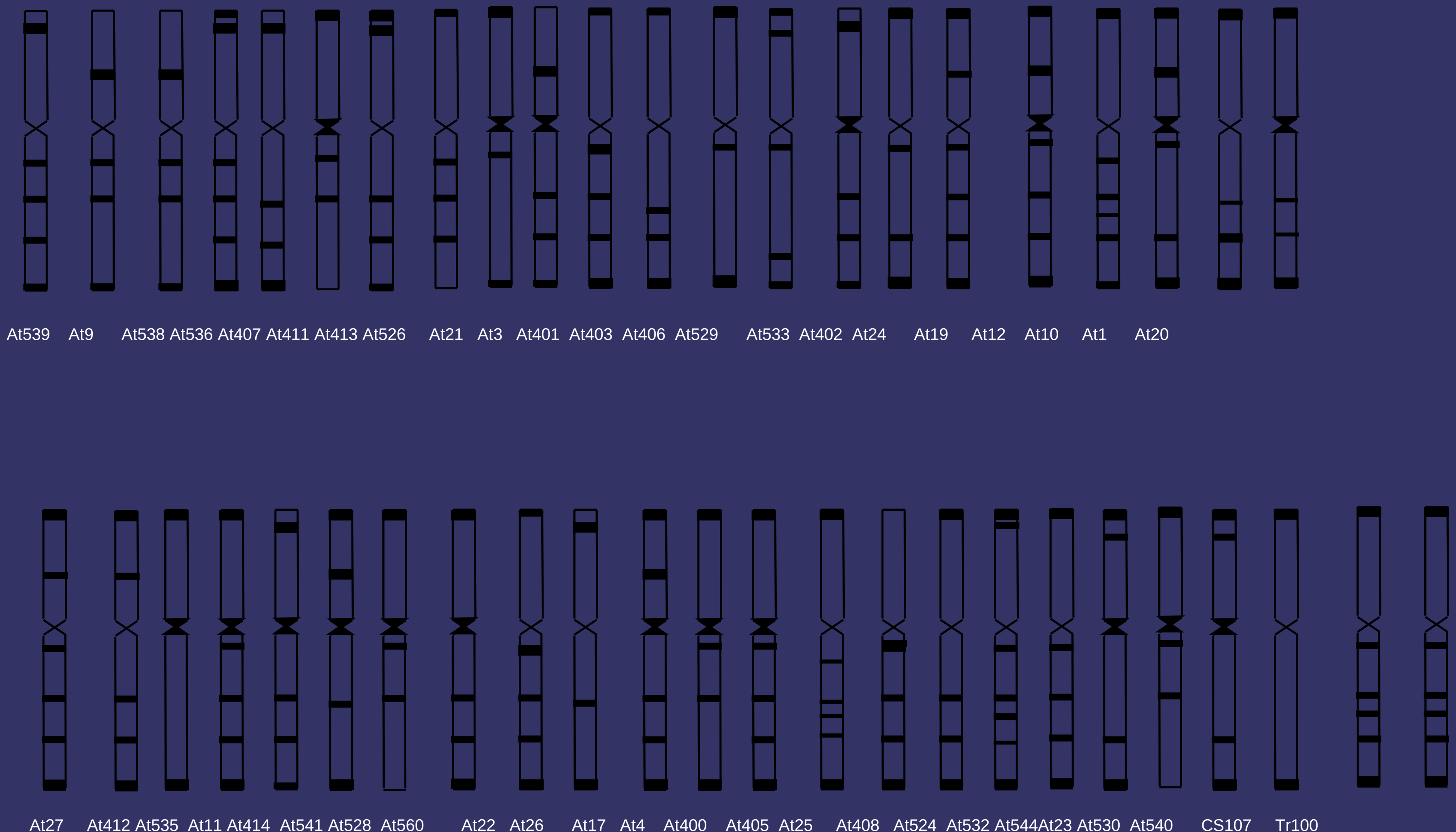
Chromosomes and Diversity

Aegilops tauschii in Iran





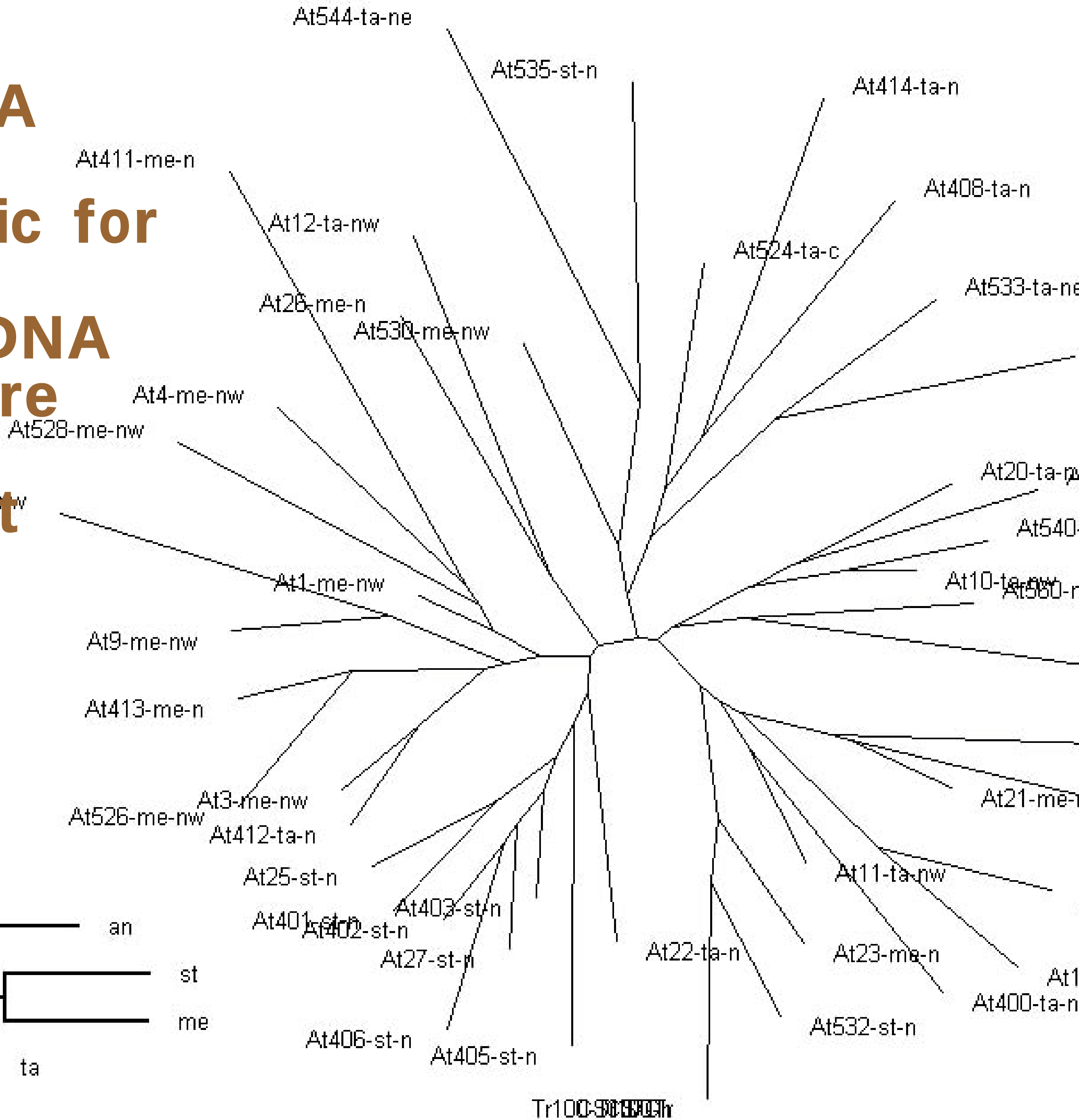
dpTa1-Repetitive banding pattern does correlate with taxonomic grouping

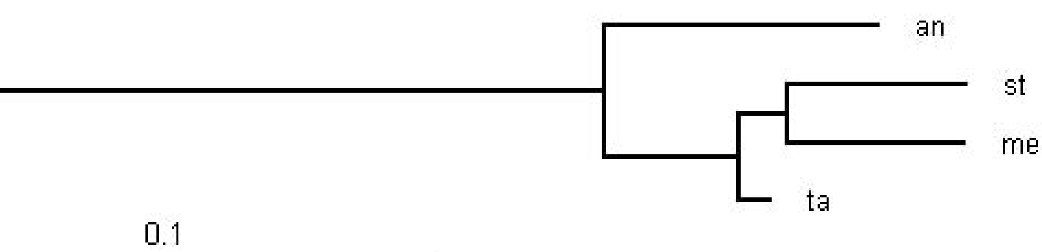

At539 At9 At538 At536 At407 At411 At413 At526 At21 At3 At401 At403 At406 At529 At533 At402 At24 At19 At12 At10 At1 At20
At27 At412 At535 At11 At414 At541 At528 At560 At22 At26 At17 At4 At400 At405 At25 At408 At524 At532 At544At23 At530 At540 CS107 Tr100

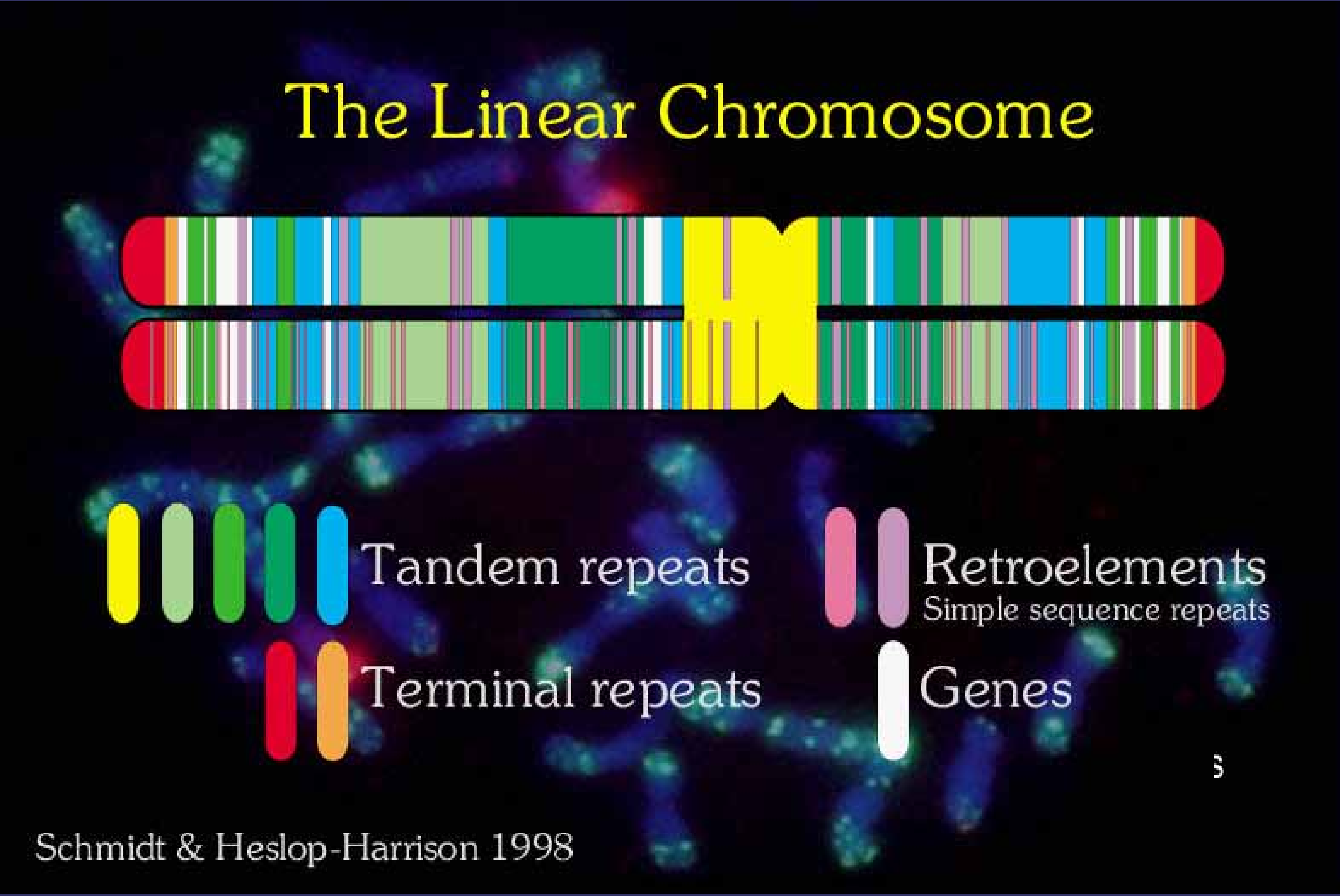
2D


At544-ta-ne
At535-st-n
At414-ta-n
At411-me-n
At408-ta-n
At533-ta-ne
At26-me-n
At407-ta-n
At4-me-nw
At528-me-nw
At20-ta-At17-an-c
At540-an-n
At10-ta-nw
At1-me-nw
At560-me-n
At9-me-nw
At538-ta-ne
At413-me-n
At21-me-n
At536-ta-ne
At11-ta-nw
At24-an-n
At22-ta-n
At23-me-n
At19-an-c
At400-ta-n
At532-st-n
Tr10CSCS-Ch
0.1

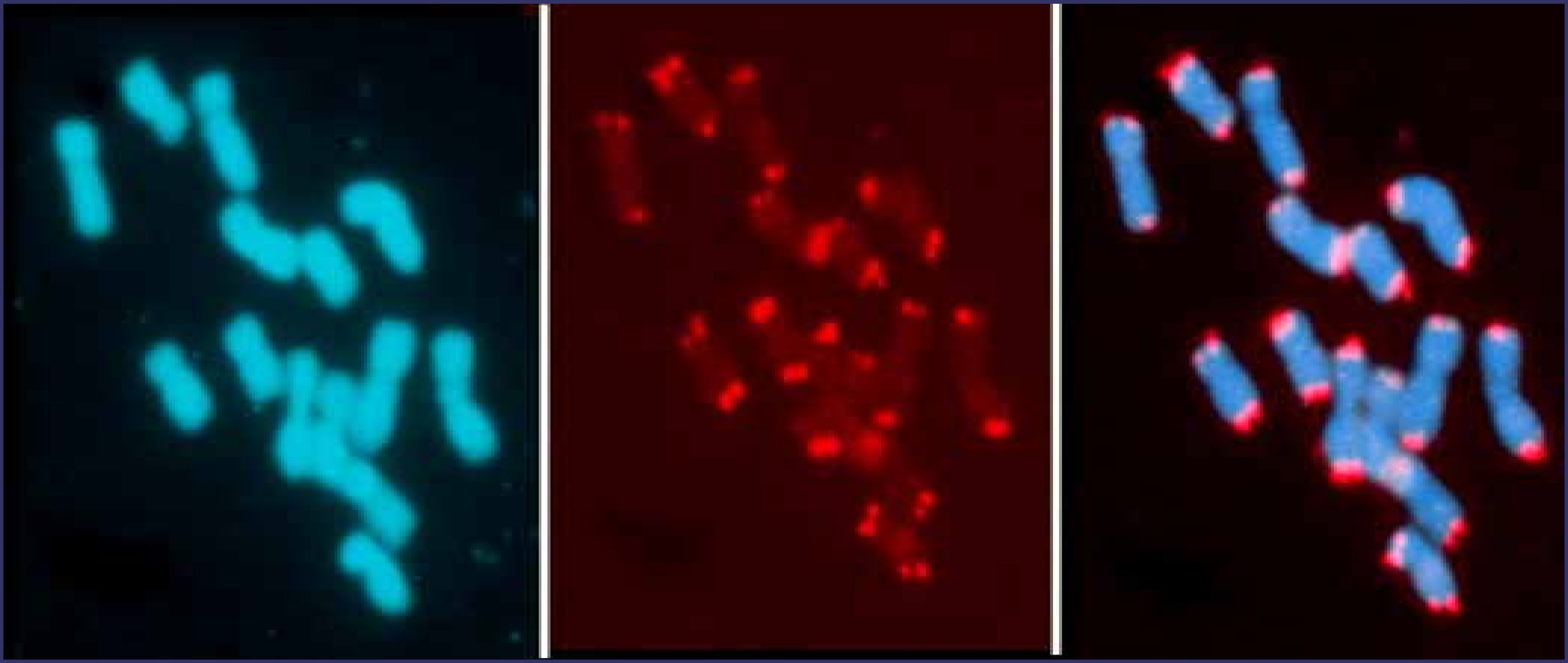
- *In situ* repetitive DNA markers
- Markers characteristic for taxa
- Evolution of tandem DNA markers and SSR are different
- High diversity present
- Useful genes for wheat breeding






The Linear Chromosome
Tandem repeats
Retroelements
Simple sequence repeats
Terminal repeats
Genes
Schmidt & Heslop-Harrison 1998

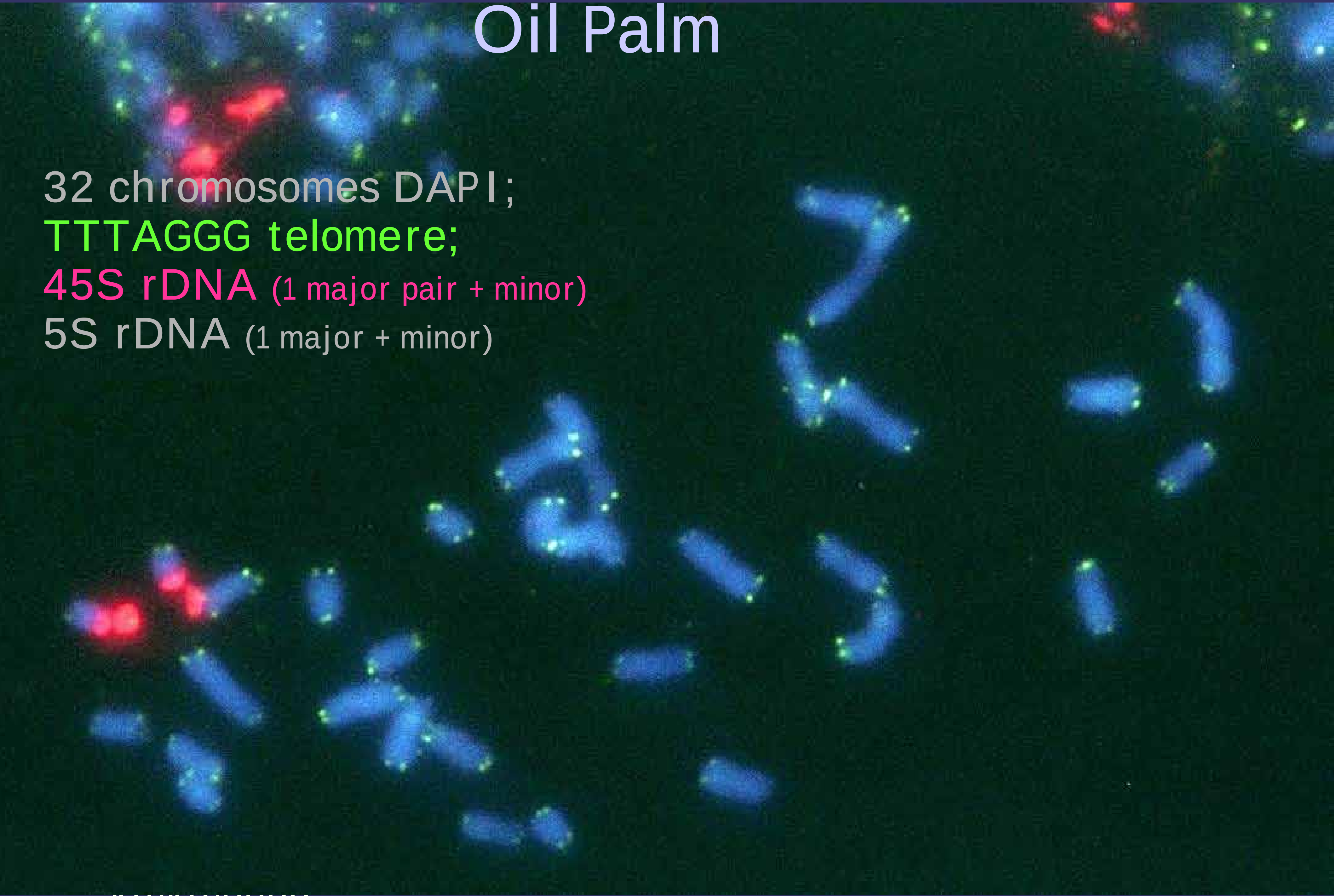
Telomere (TTTAGGG)n

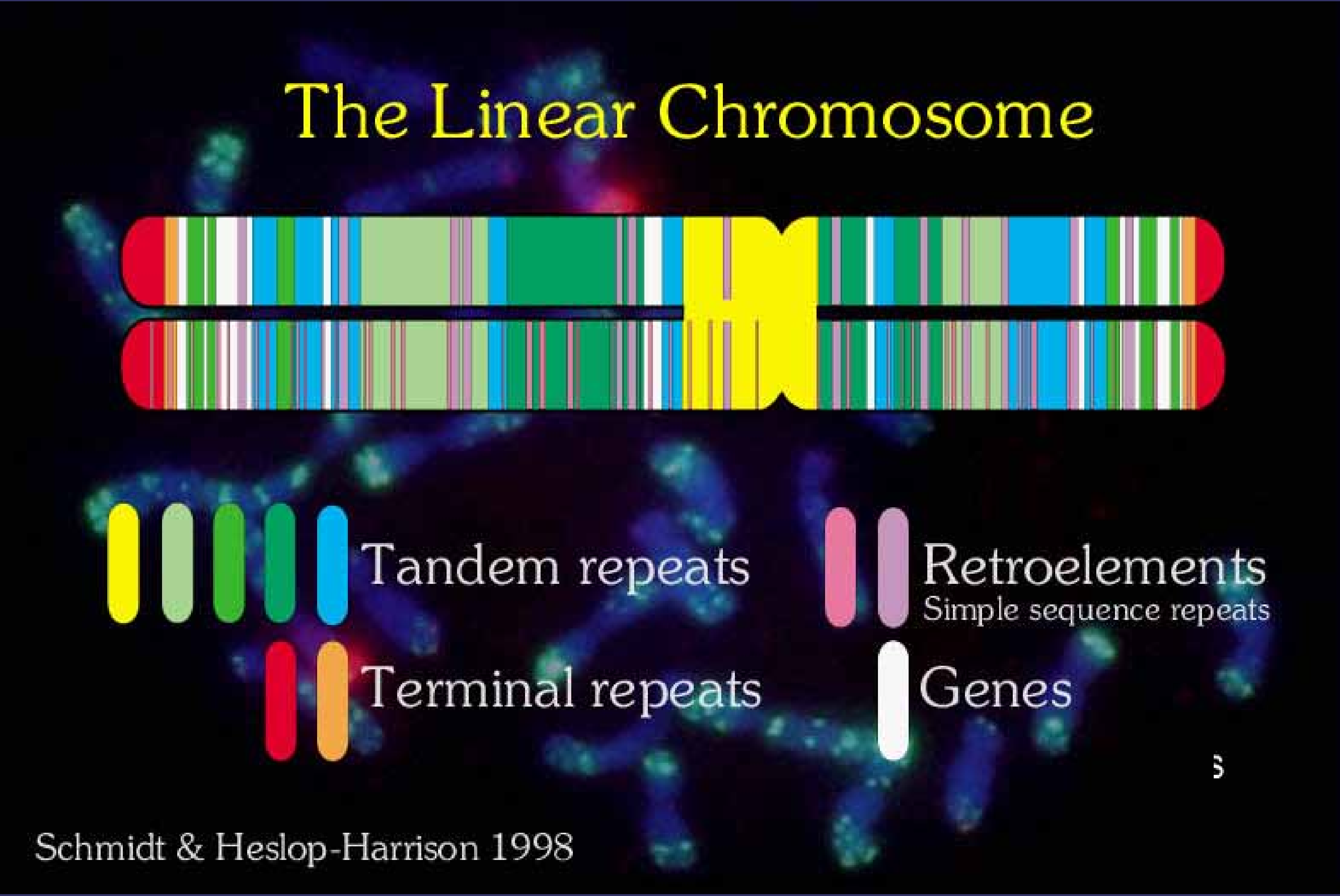


- Universal in eukaryotes with only a few exceptions
- Dynamic
- Number of repeats varies: tissue, age and chromosome
- Added by telomerase

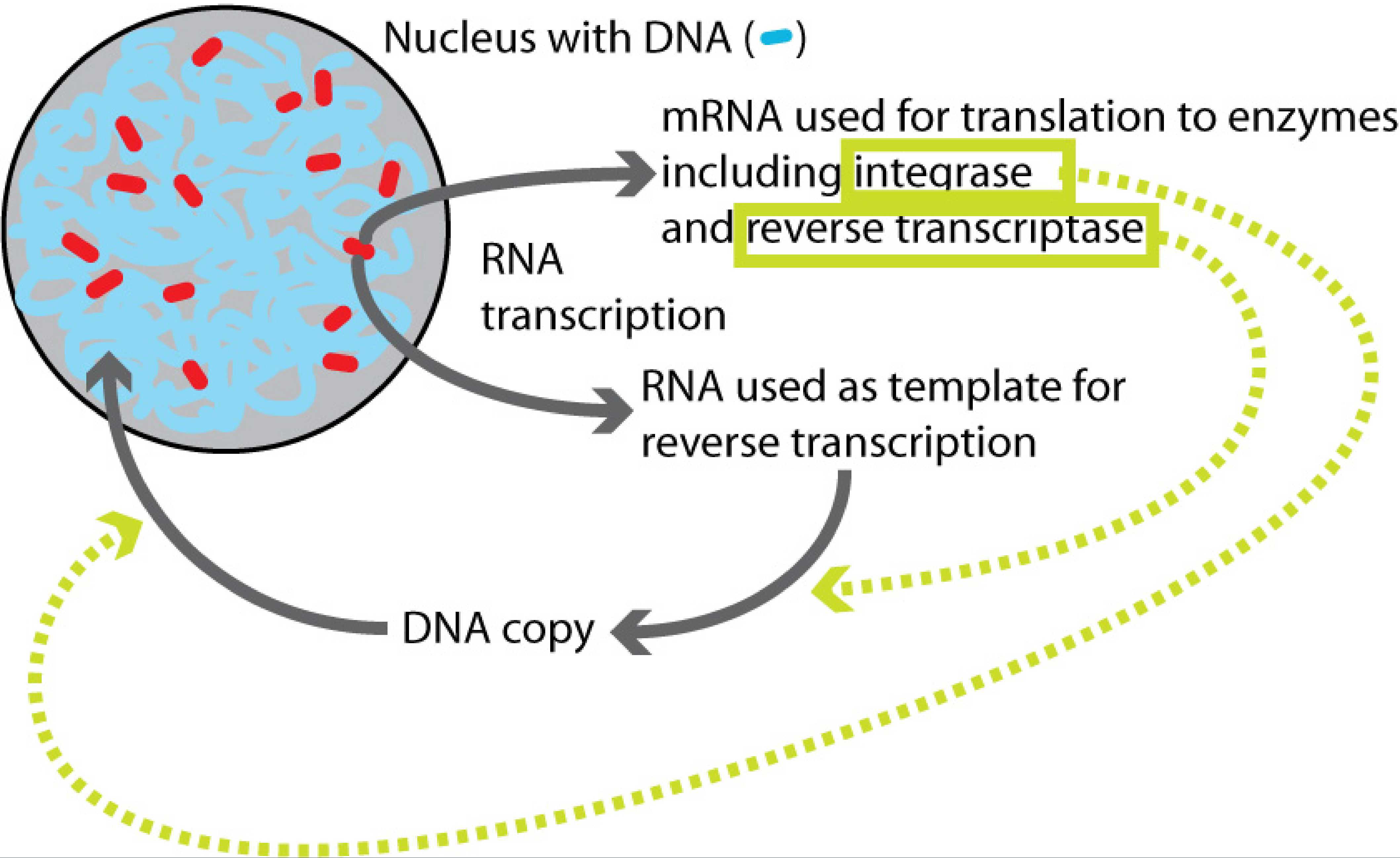
Oil Palm

32 chromosomes DAPI;
TTTAGGG telomere;
45S rDNA (1 major pair + minor)
5S rDNA (1 major + minor)



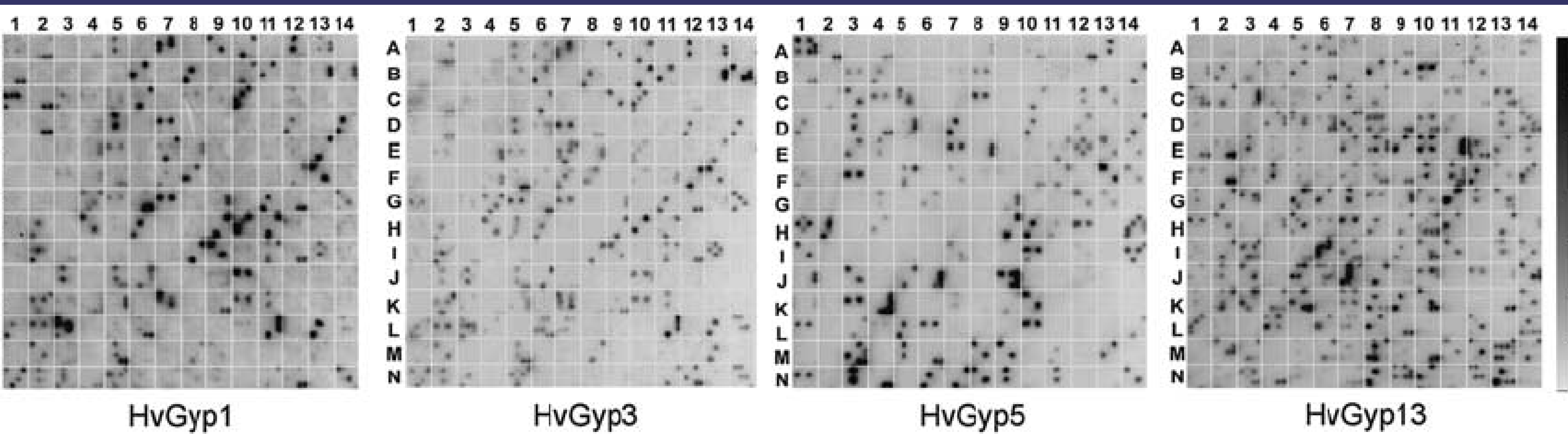

The Linear Chromosome
Tandem repeats
Retroelements
Simple sequence repeats
Terminal repeats
Genes
Schmidt & Heslop-Harrison 1998

Retrotransposons (▬): The transposition cycle

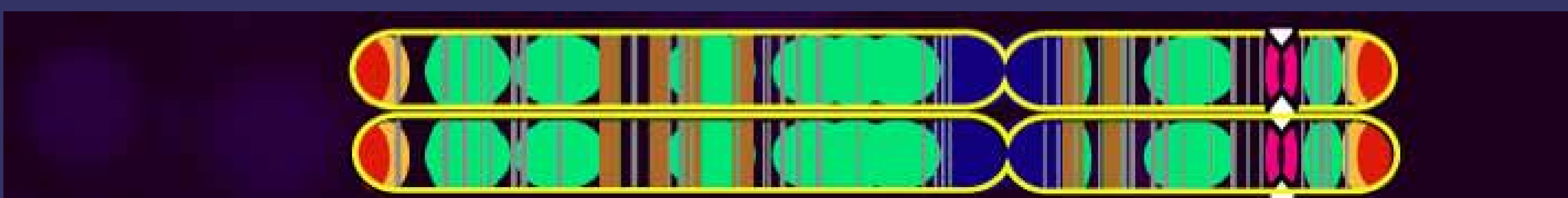



PLANT
MOLECULAR
BIOLOGY
International Society for
Plant Molecular Biology
Springer
Retroelements in Brassica

Retroelements in barley



Gypsy elements are present in 25% of all BAC clones

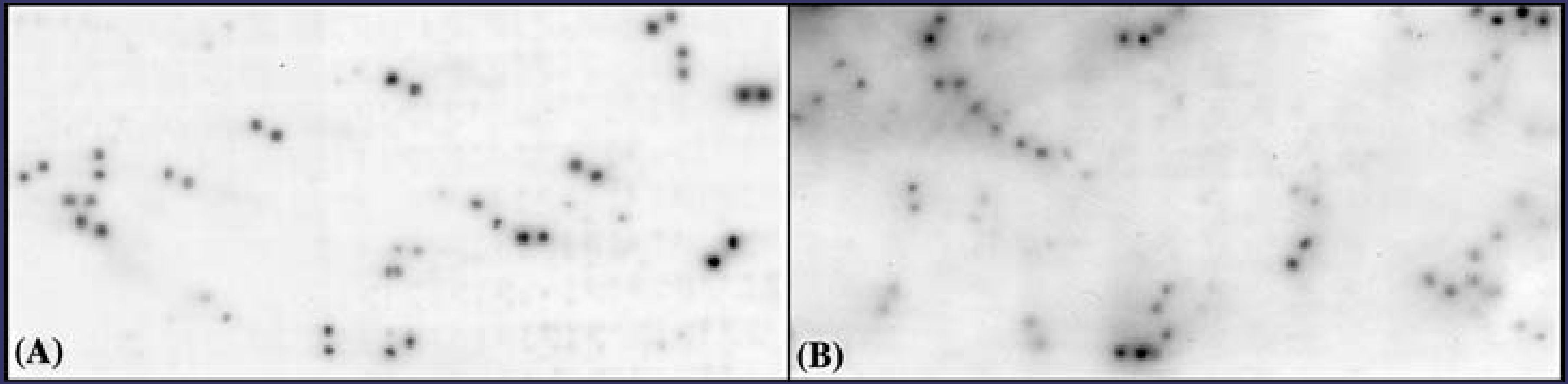


Barley gypsy: Vershinin, Druka, Kleinhofs, HH: PMB 2002; cf Brassica Alix & HH PMB 2005

Brassica retrotransposons

1088 BACs on the same high-density filter

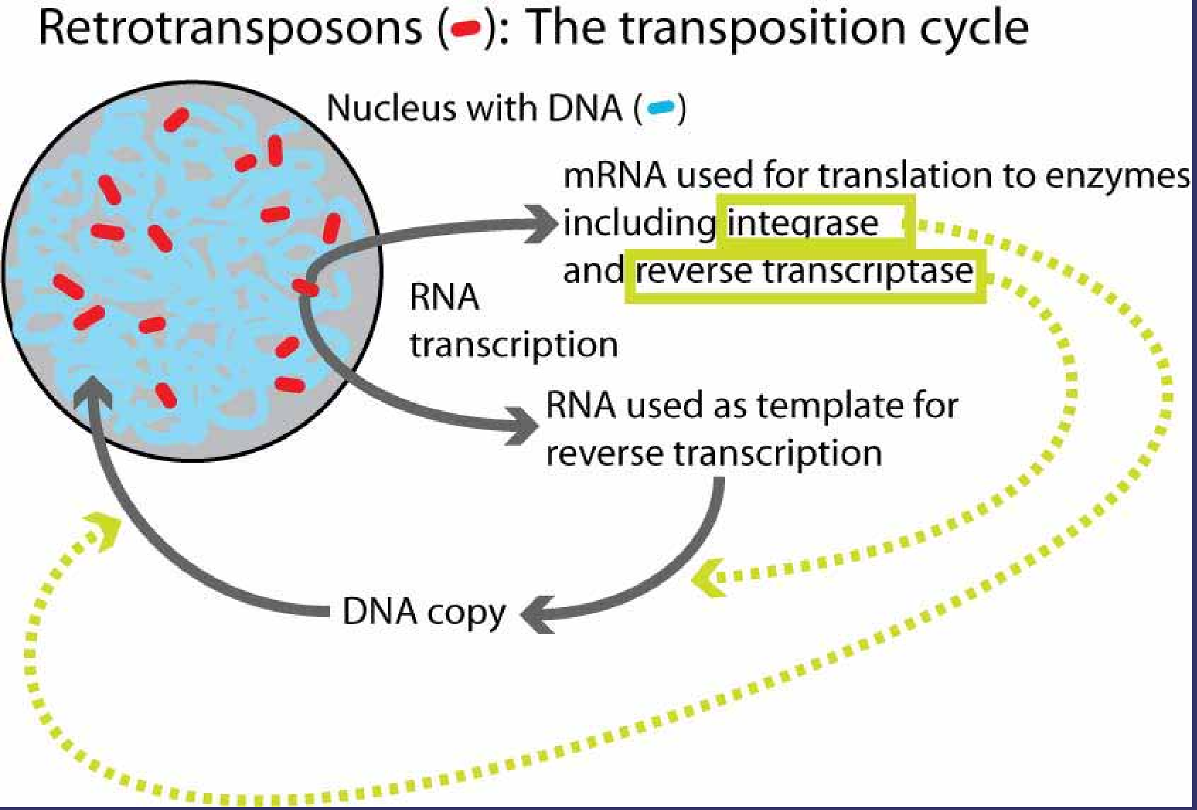
copia RT probe (18)   gypsy RT probe (25)



Minimal clustering within BACs, different retroelements have contrasting genomic distributions. Very few LINE elements; Total retroelements c. 15% of genome but diverse families of copia and gypsy each <1%.

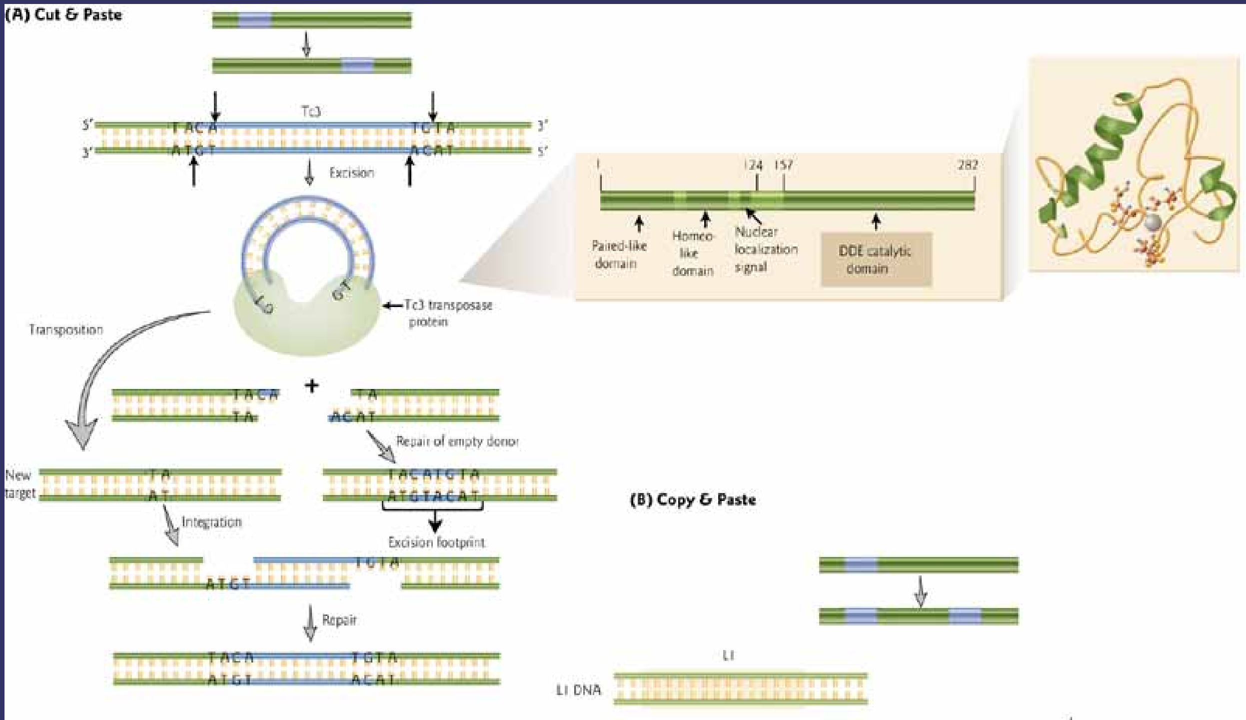
Analysis by BAC sequences, Genomic Survey Sequence (GSS), Southern and BAC filter hybridization, in situ hybridization

Alix et al. The genomic organization of retrotransposons in *Brassica oleracea*. Plant Molecular Biology 59: 839



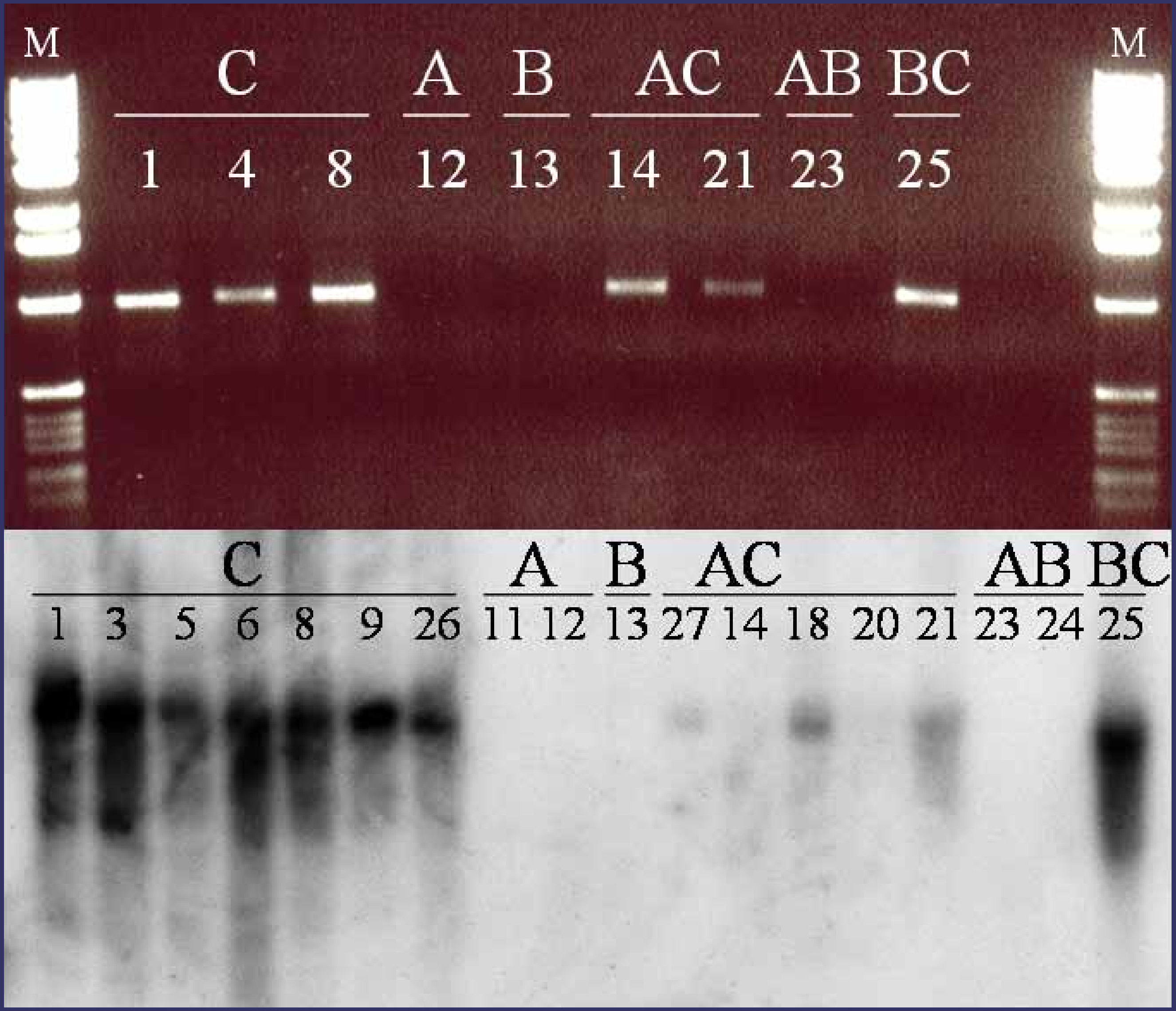
DNA transposons
Class II transposable elements
Cut-and-paste

Retrotransposons
Class I transposable elements
RNA intermediate



Genome Specificity of a CACTA (*En/Spm*) Transposon

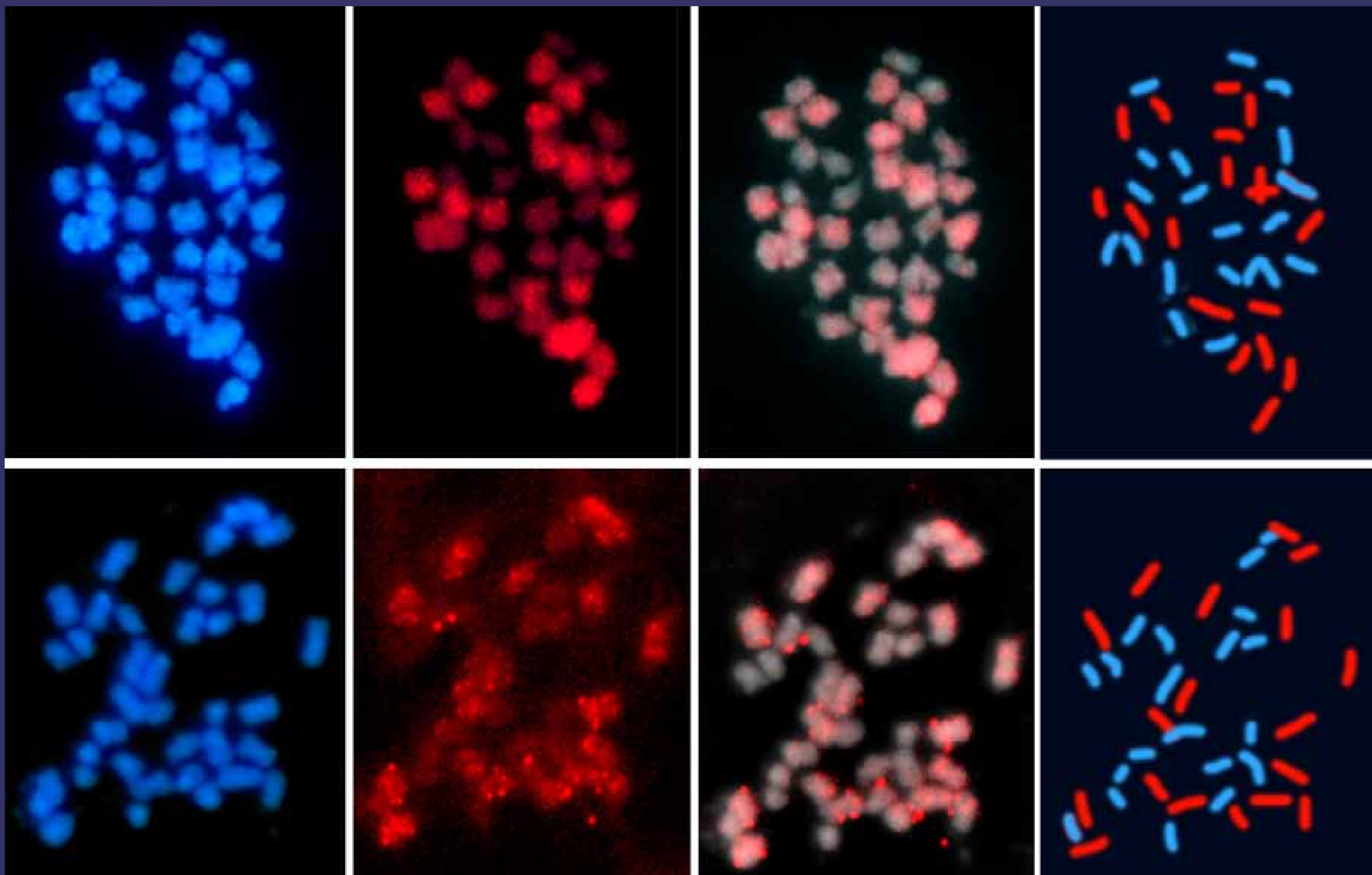
B. napus (AACC, 2n=4x=38) **B. oleracea (CC, 2n=2x=18)** **B. rapa (AA, 2n=2x=20)**



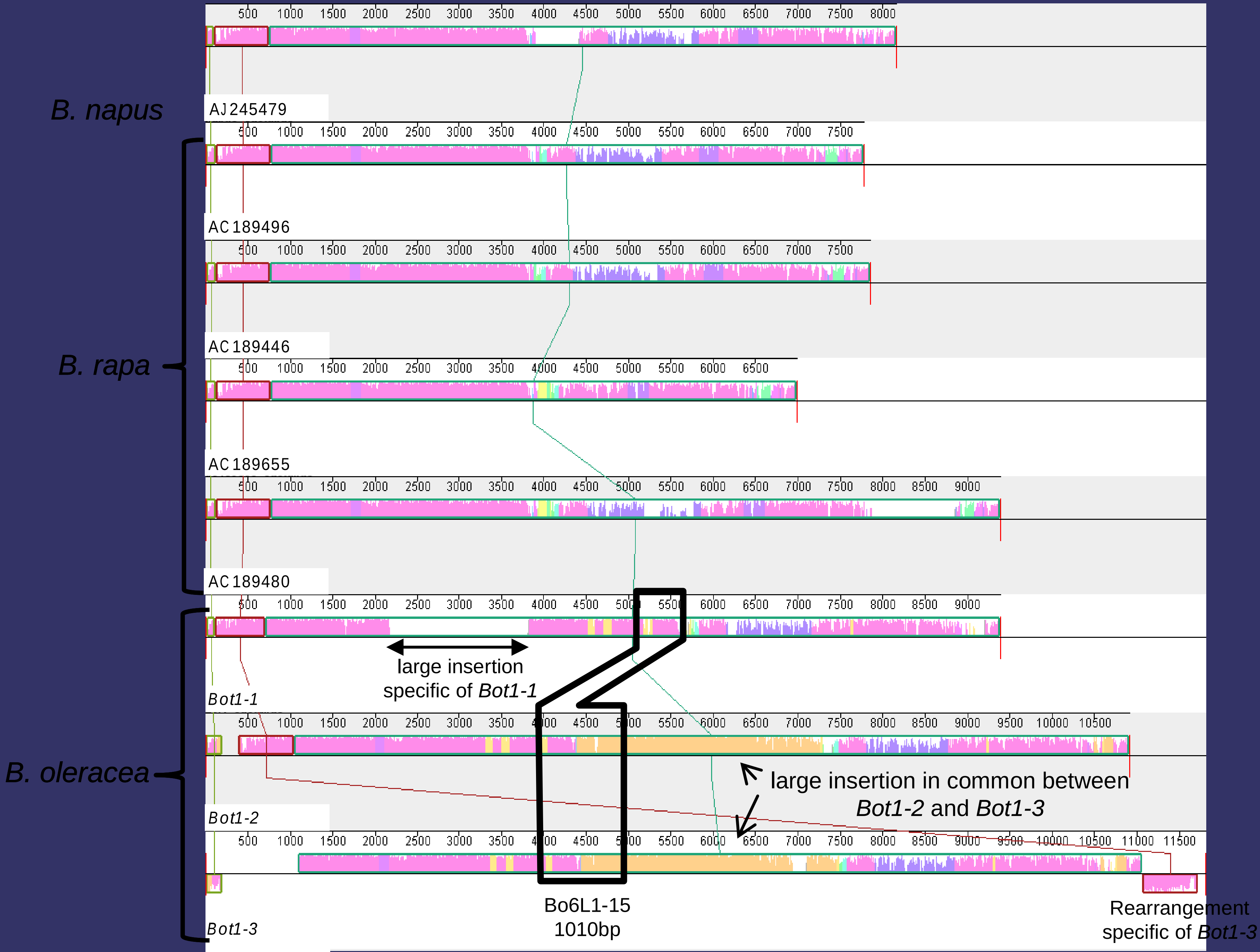
Genome Specificity of a CACTA (*En/Spm*) Transposon

B. napus **(AACC, 2n=4x=38) – hybridized with C-genome CACTA element red**

B. oleracea (CC, 2n=2x=18) **B. rapa (AA, 2n=2x=20)**



Genome Specificity of a CACTA (En/Spm) Transposon



Genome Specificity of a CACTA (En/Spm) Transposon

Bot1 has encountered several rounds of amplification in the C (*B. oleracea)* genome
only, playing a major role in the recent *B. rapa*
and *B. oleracea* genome divergence
Bot1 carries a host S-locus associated *SLL3* gene copy; is the transposon associated with *SLL3* proliferation?

à Transposons are a driver of genome and genome evolution

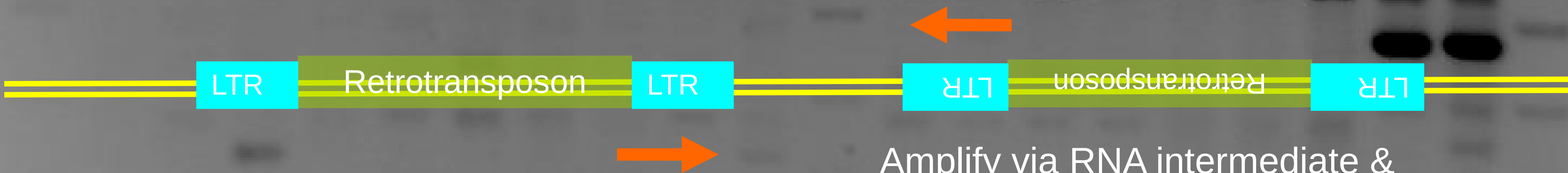
Alix et al. The CACTA transposon Bot1 played a major role in *Brassica* genome divergence and gene proliferation. Plant Journal December 2008

Markers for studying diversity and relationships

Microsatellites or simple sequence repeats (SSRs)

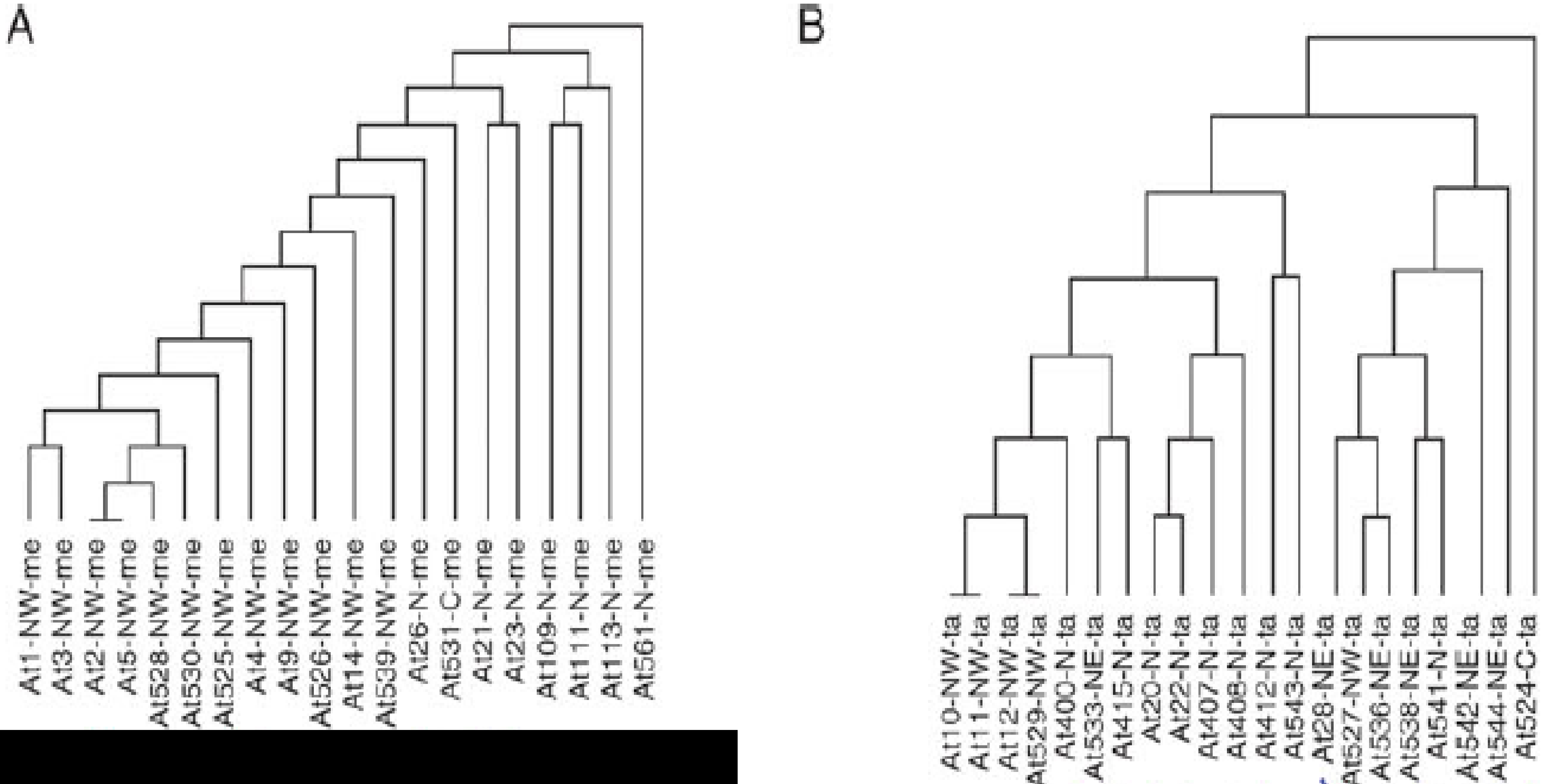
e.g. GAGAGAGAGAGAGAGA
Change number of repeats spontaneously

IRAPs



Amplify via RNA intermediate &
Insert all over the genome

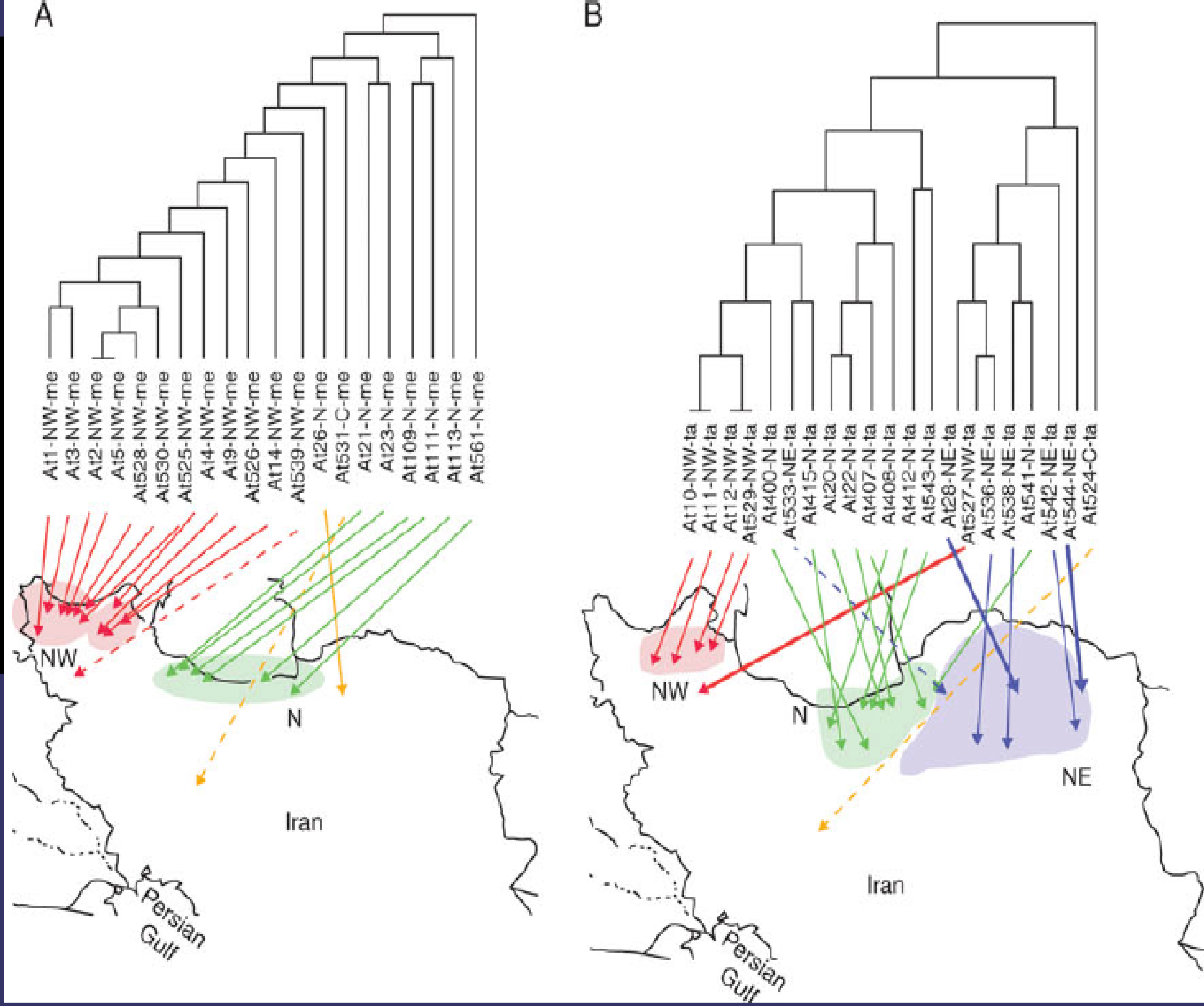
Inter-Retroelement Amplified Polymorphisms



Ae. tauschii subsp. *tauschii* var. *meyeri*

Ae. tauschii subsp. *Tauschii* var. *tauschii*

Retroelement insertional polymorphisms, diversity and phylogeography within diploid, d-genome Aegilops tauschii (Triticeae, Poaceae) sub-taxa in Iran. Saeidi, 2008. Annals of Botany



Ae. tauschii subsp. *tauschii* var. *meyeri* *Ae. tauschii* subsp. *tauschii* var. *tauschii*

superimposed on their geographic origins

Saeidi et al. 2008. Annals of Botany

Demonstration of the direction of distribution (phylogeography) even over short geographic distances

Phylogeography of *Ae. tauschii*
Species originated from North of Iran and distributed in two directions.

tauschii genotype passes from middle parts of Alborz Mountains and the distributed eastward and westward (direction 1)

strangulata genotype are distributed along the Caspian Sea shore (direction 2)

Repetitive Sequences

The majority of the genomic DNA in most species (95% sometimes)

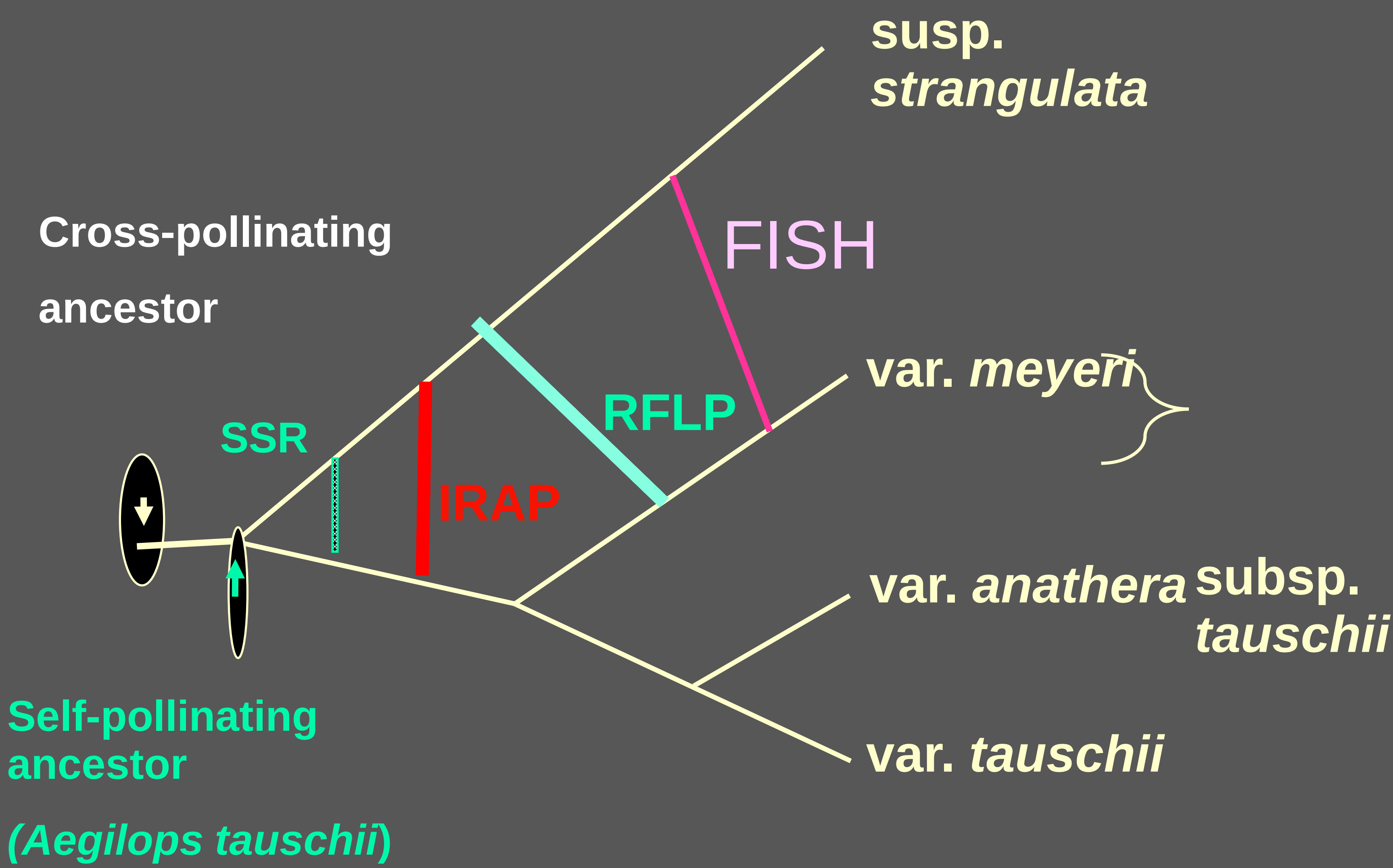
Tandem Repeats

Simple Sequence Repeats

Dispersed Repeats

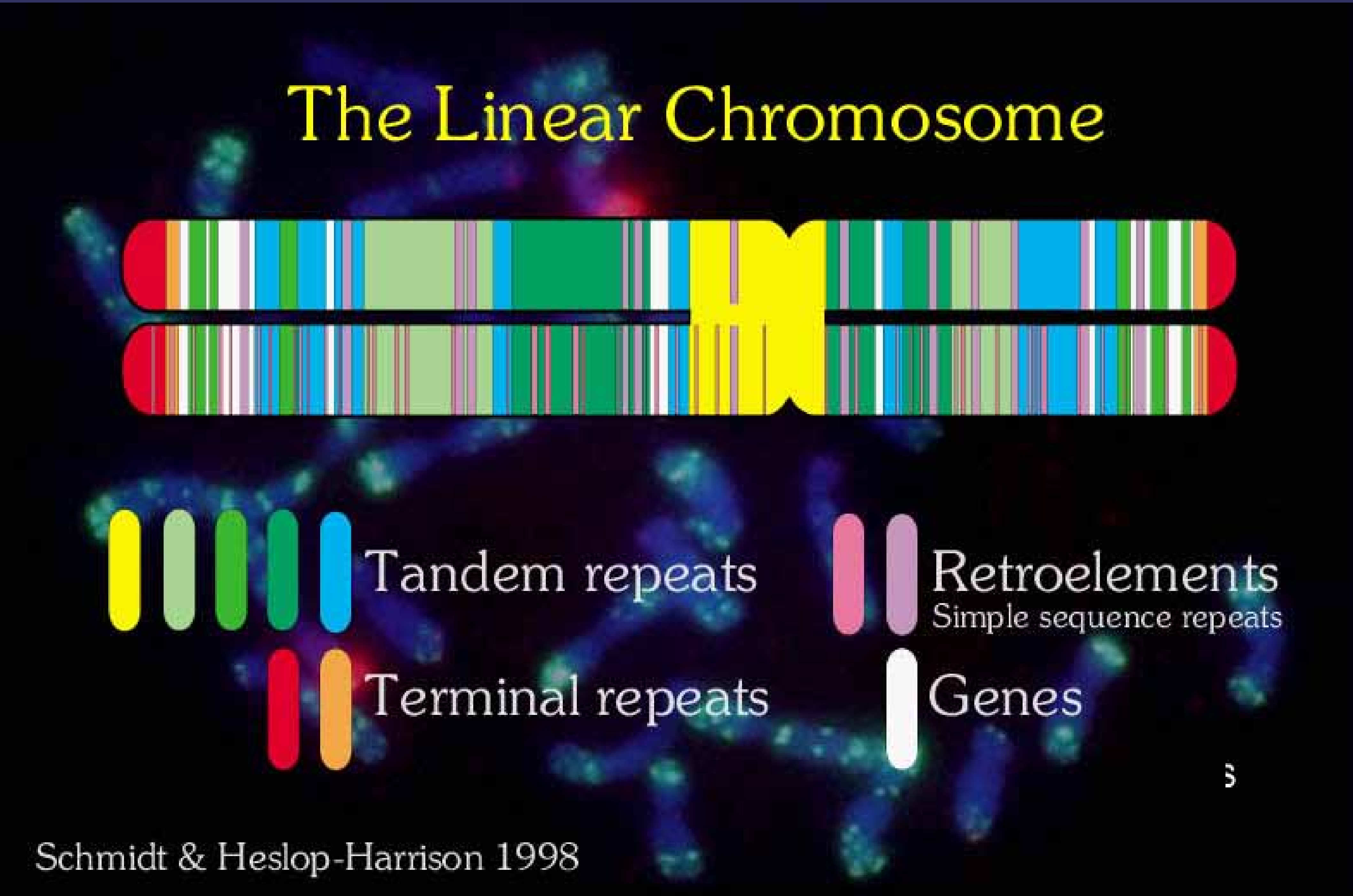
Functional Repeats

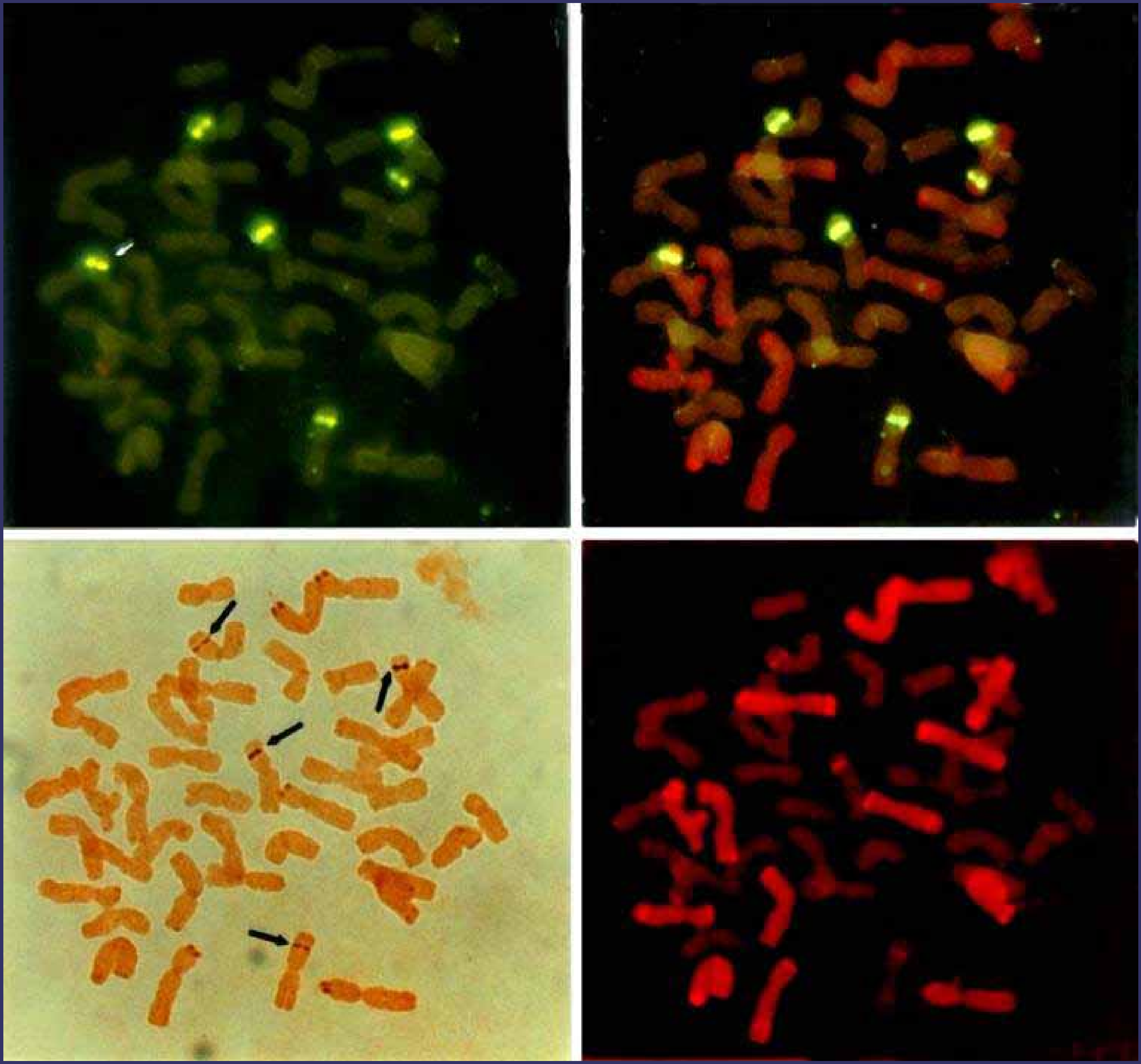
Retroelements



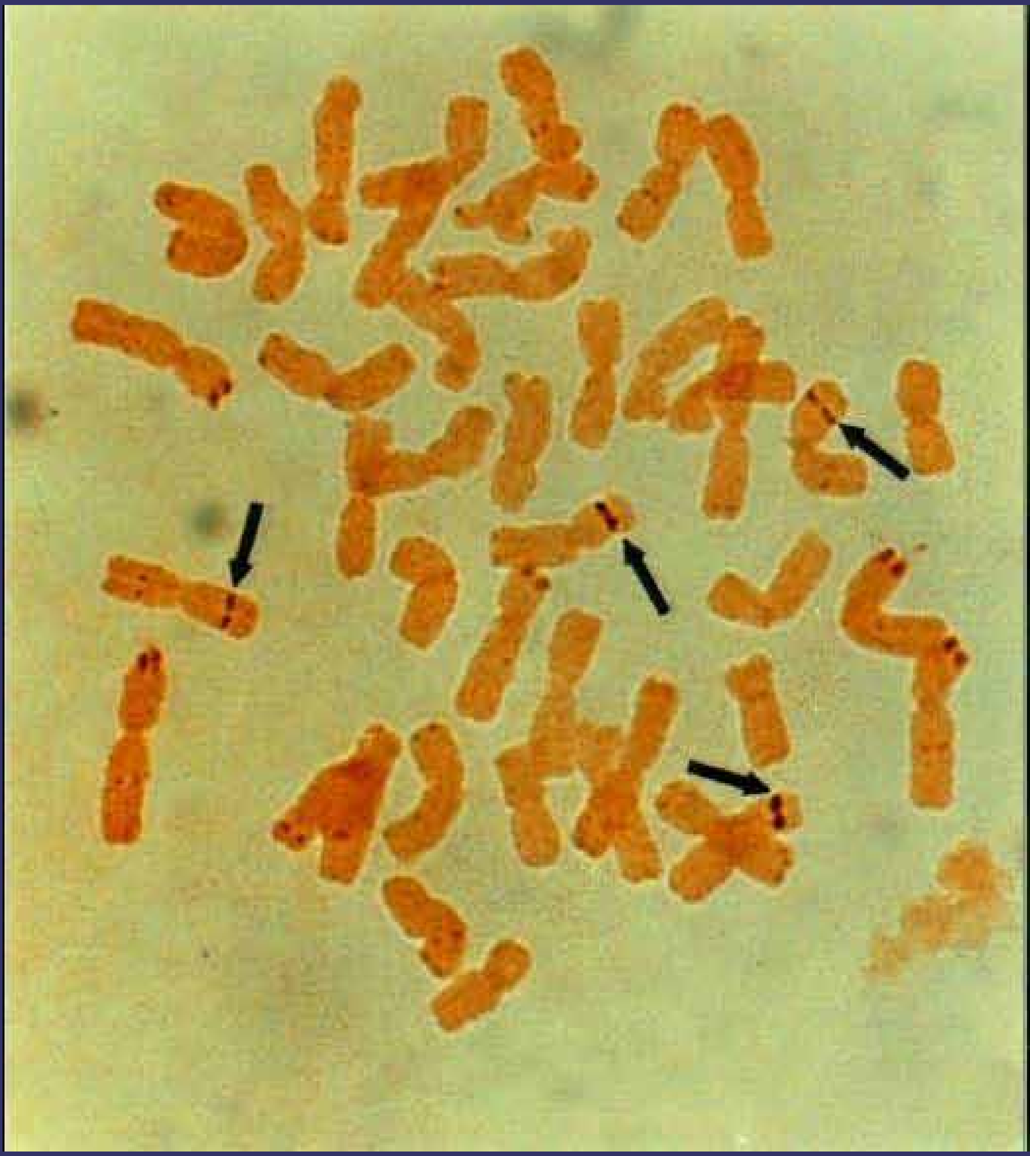
An evolutionary model supported by molecular analyses

Saeidi, HH et al. 2010

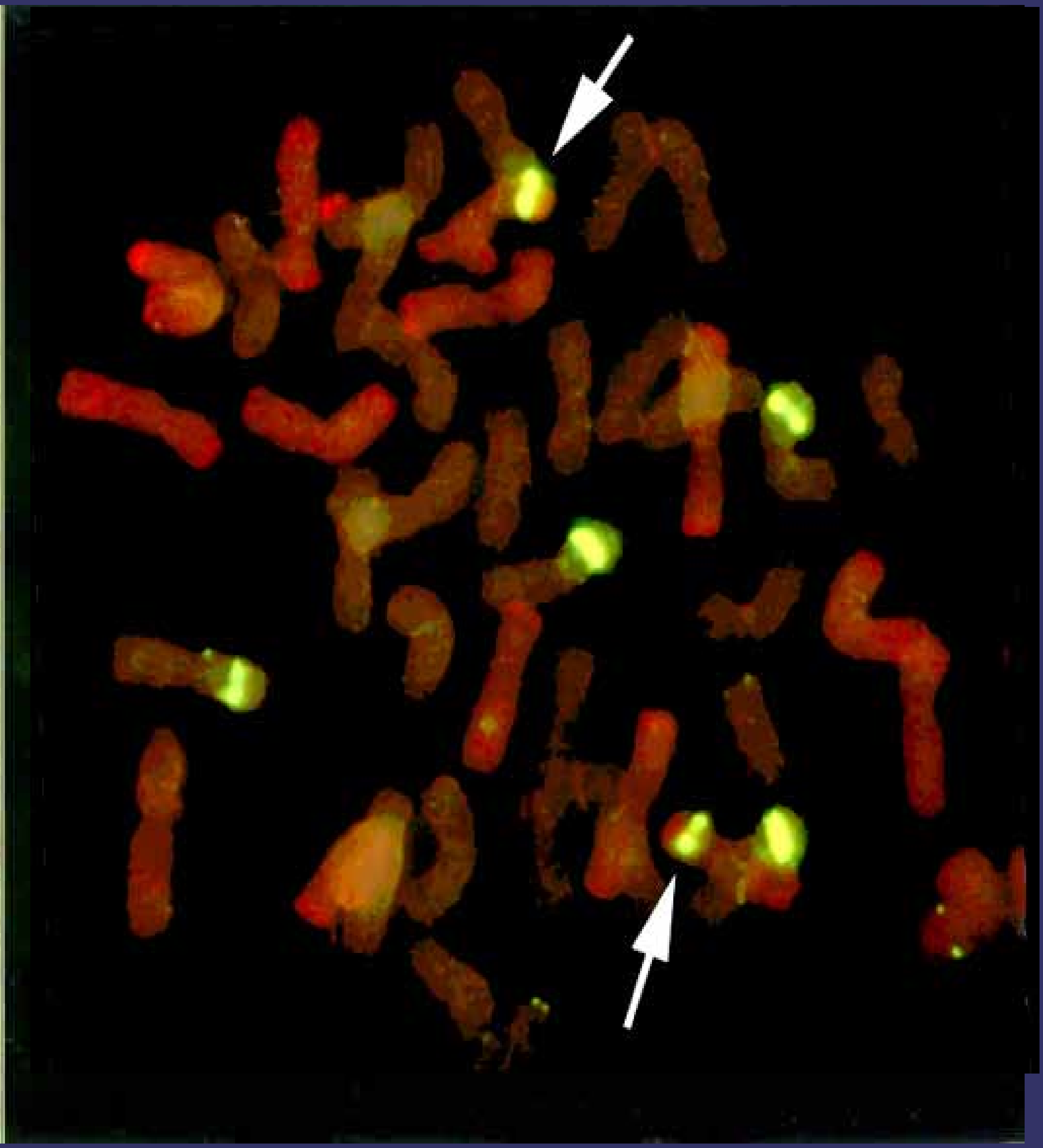

The Linear Chromosome
Tandem repeats
Retroelements
Simple sequence repeats
Terminal repeats
Genes
Schmidt & Heslop-Harrison 1998



rRNA gene expression in Triticale



Four expression sites

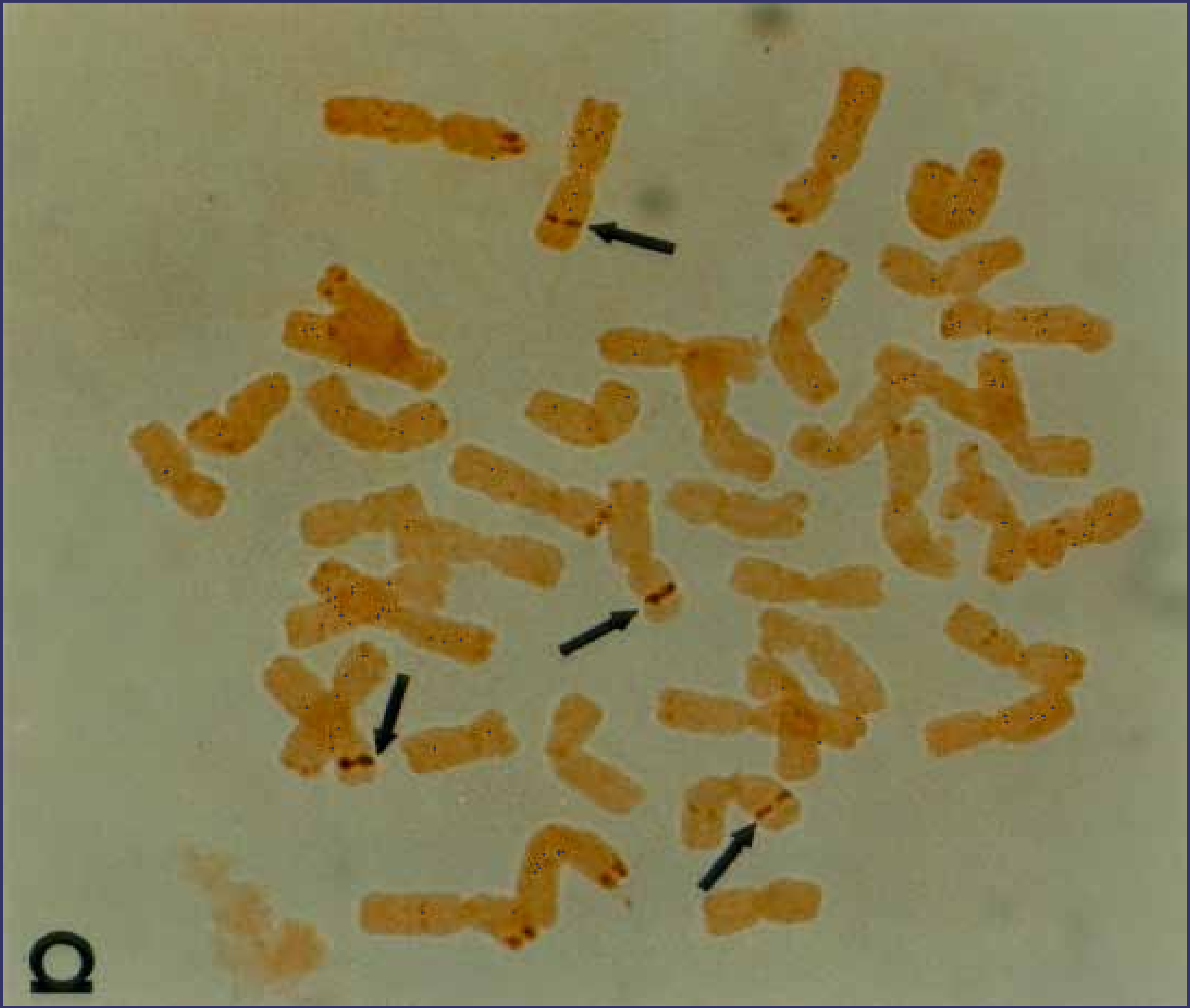


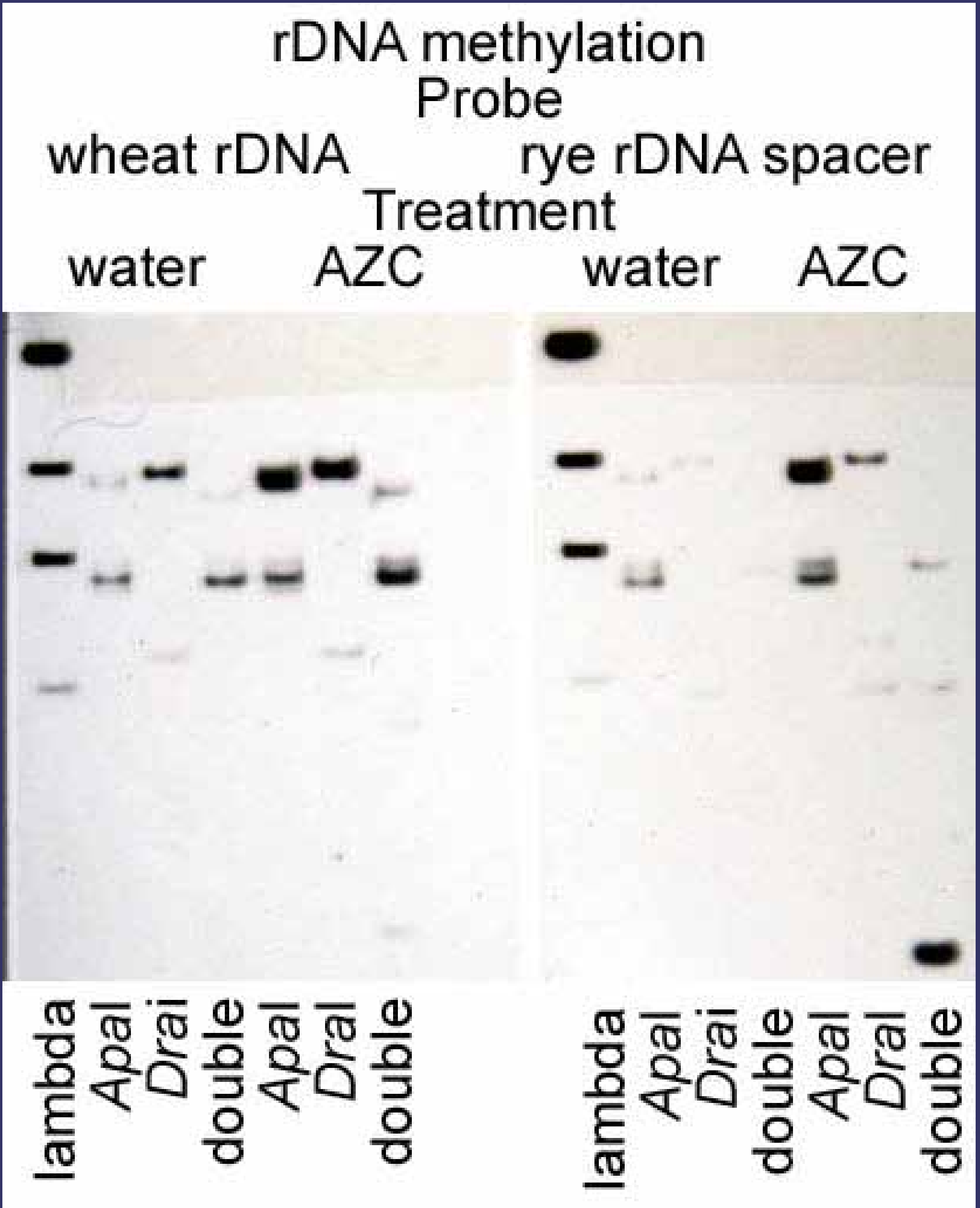
Six gene sites

Modification of DNA Methylation

- Methylation widely implicated in gene expression control
- Treat with 5-azacytidine
  - N at carbon-5 position not C so $-CH_3$ cannot be added
- Effect of treatment on Triticale

- Ag-NOR method
  - see www.methods.molcyt.com methods page




rDNA methylation
Probe
wheat rDNA
rye rDNA spacer
Treatment
water
AZC
water
AZC
lambda
ApaI
DraI
double
ApaI
DraI
double
lambda
ApaI
DraI
double
ApaI
DraI
double

Modification of rDNA Methylation

Stability of methylation

Seedling treatment – all 6 active for life

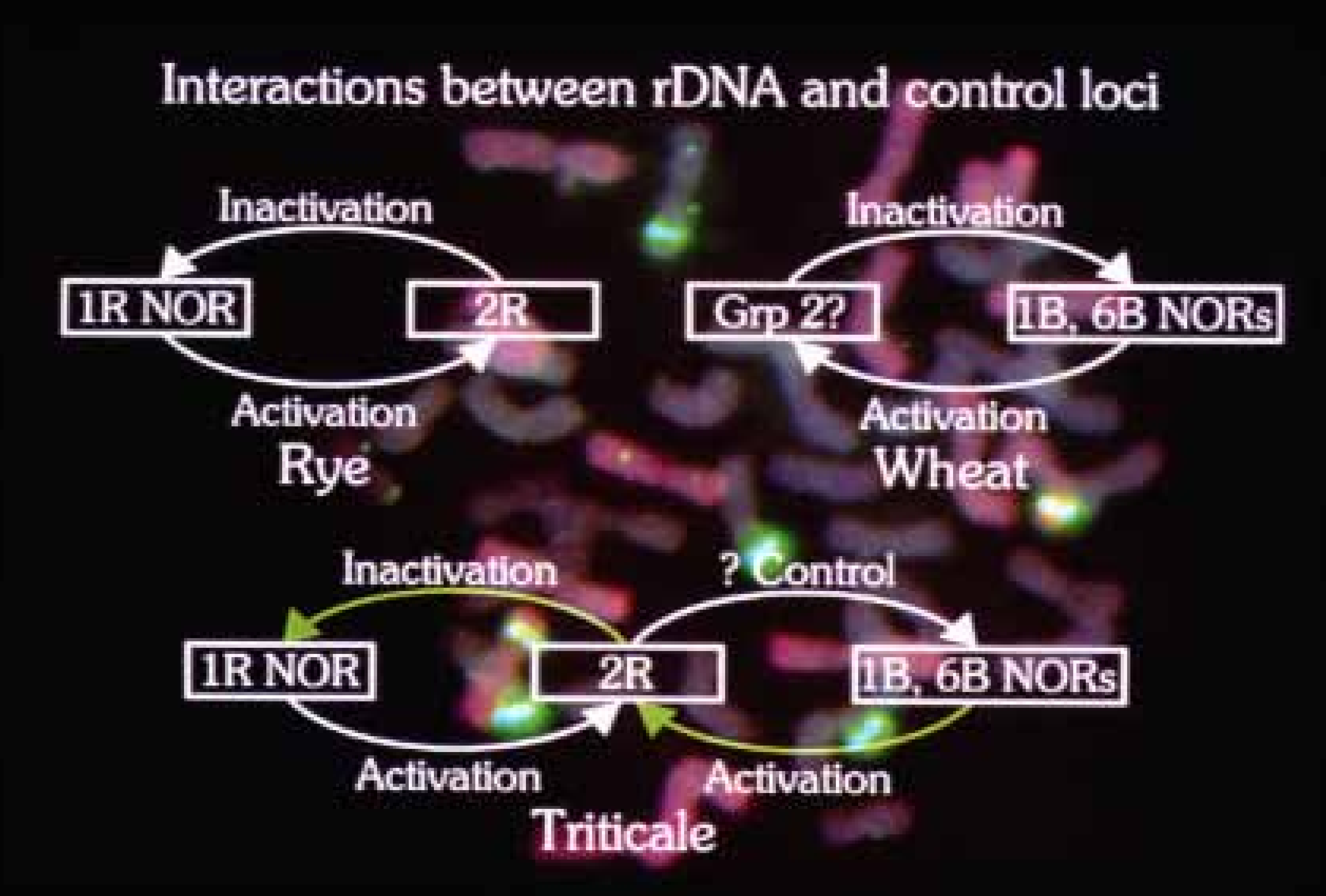
Embryo treatment:
First 7 days – only wheat-origin active
After 7 days – rye and wheat-origin active

rDNA expression in Triticale

Observation:
Ag-staining showed 6 NORs sometimes

These were in triticale with 12 rye chromosomes: 2D-2R substitution

Found rather frequently so breeders must select it


Interactions between rDNA and control loci
Inactivation
1R NOR
2R
Activation
Rye
Inactivation
Grp 2?
1B, 6B NORs
Activation
Wheat
Inactivation
1R NOR
2R
Activation
? Control
1B, 6B NORs
Activation
Triticale

Oil palm: *Elaeis guineensis*

Malaysian Palm Oil Board
Alex Vershinin, Sybille Kubis,
Maria Madon, Xana Castilho,
Trude Schwarzacher


Deli Dura (D)
DxP
Pisifera (P)

Epigenetics

Phenotype appears 5 years after tissue culture

Modulation of Methylation

McrBC

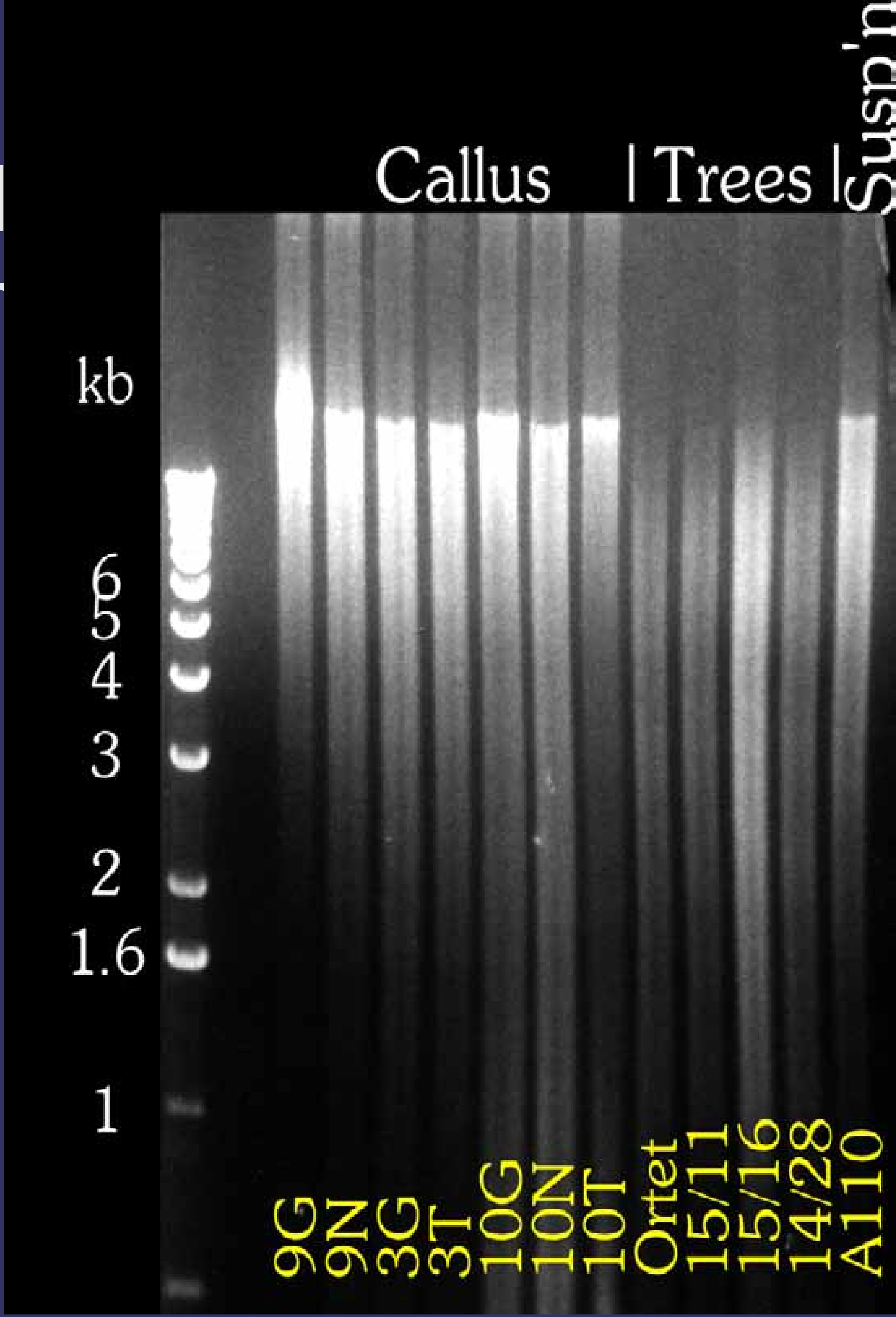
unusual restriction enzyme cutting between methylated cytosine (^{m}C) sites

Cuts ^{m}C *NNNNNNNNNNNN* ^{m}C

Leaves *C NNNNNNNNNNNN C*

N typically 20 to 40 bases

Modul
Meth

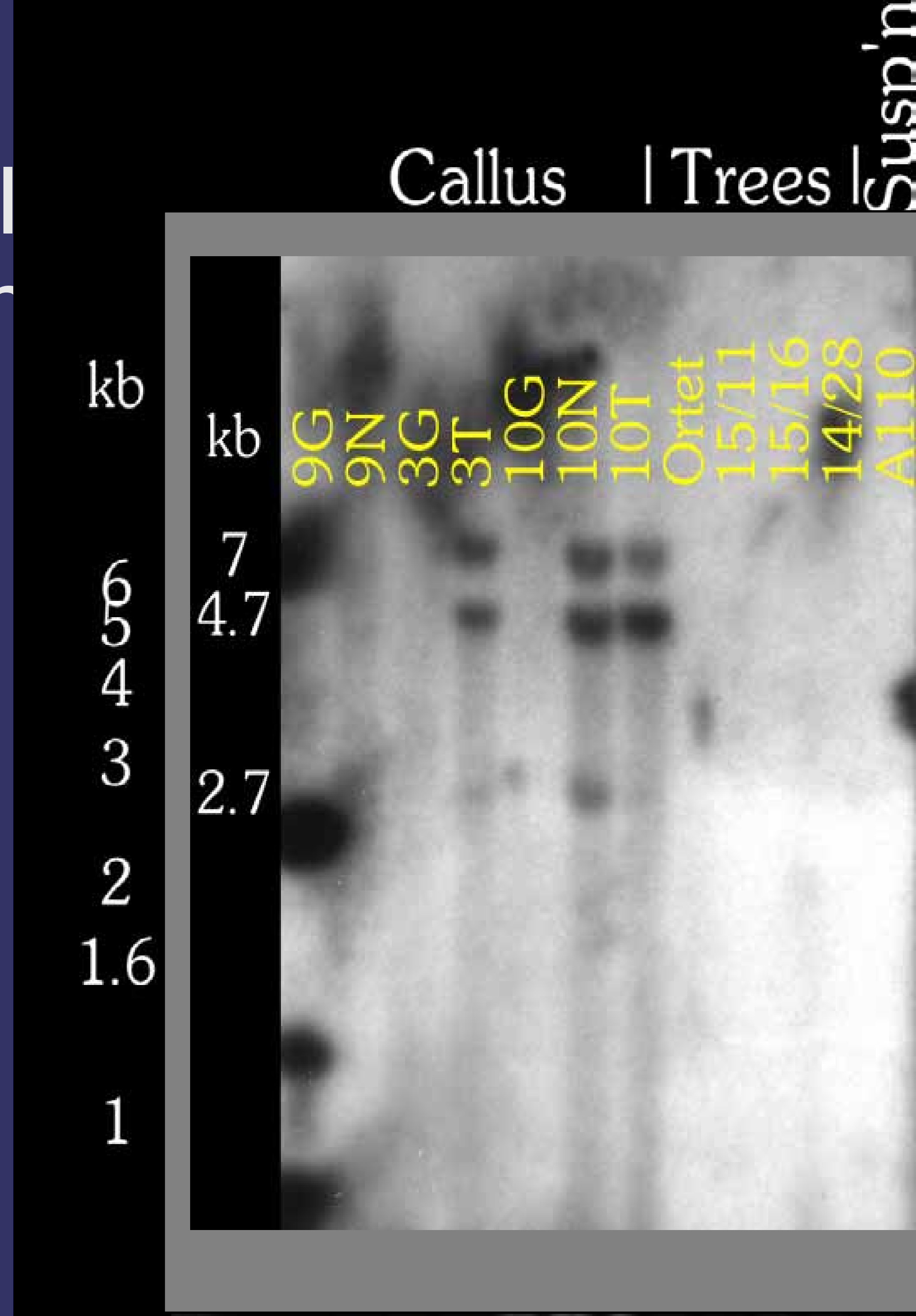


McrBC - shows substantial reduction in methylation in tissue culture lines

Cuts methylated DNA

Kubis, Castilho, Vershinin, HH 2003

Modul
Meth



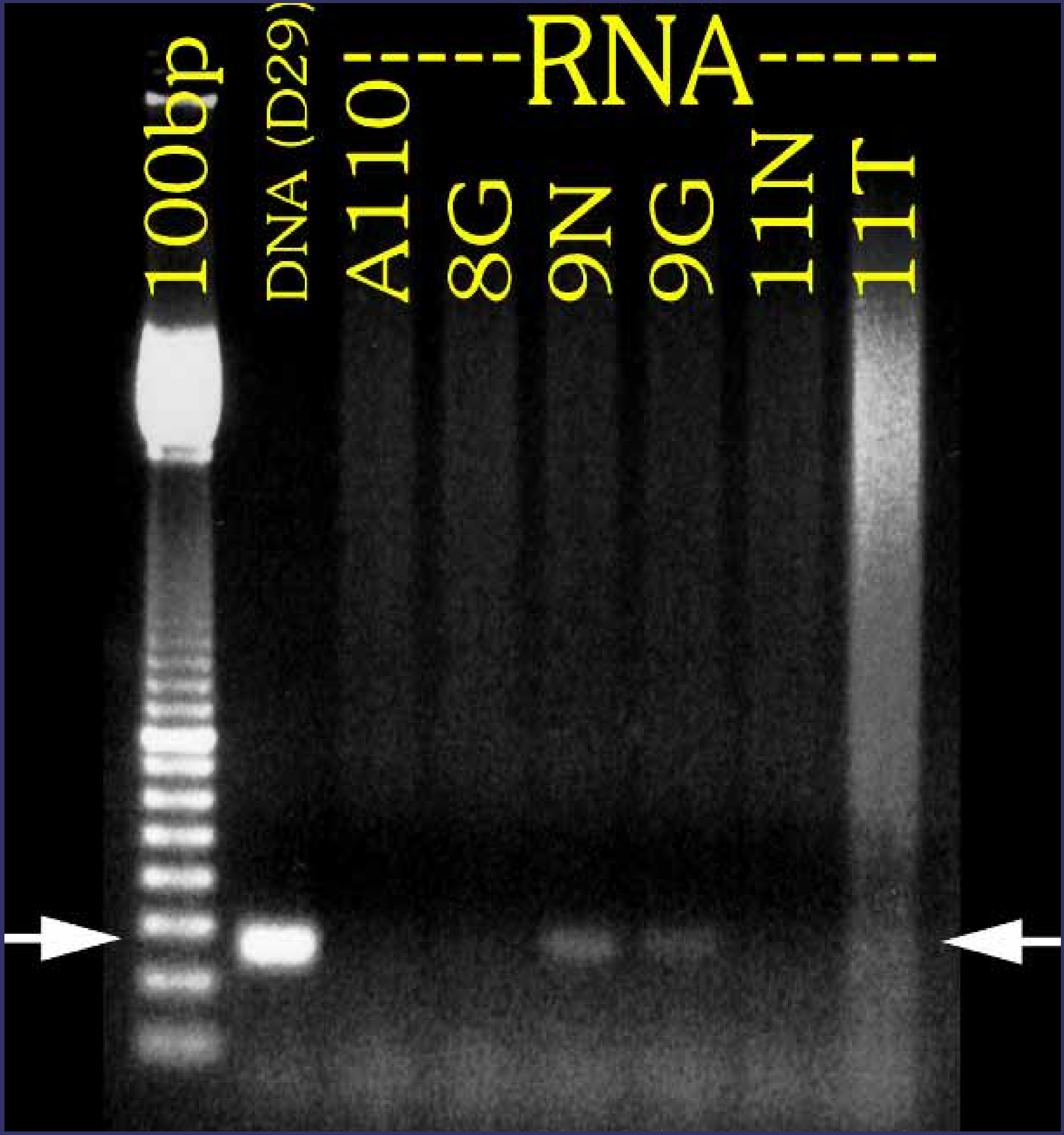
McrBC digests probed with *gypsy* clones

present only in N and T lines

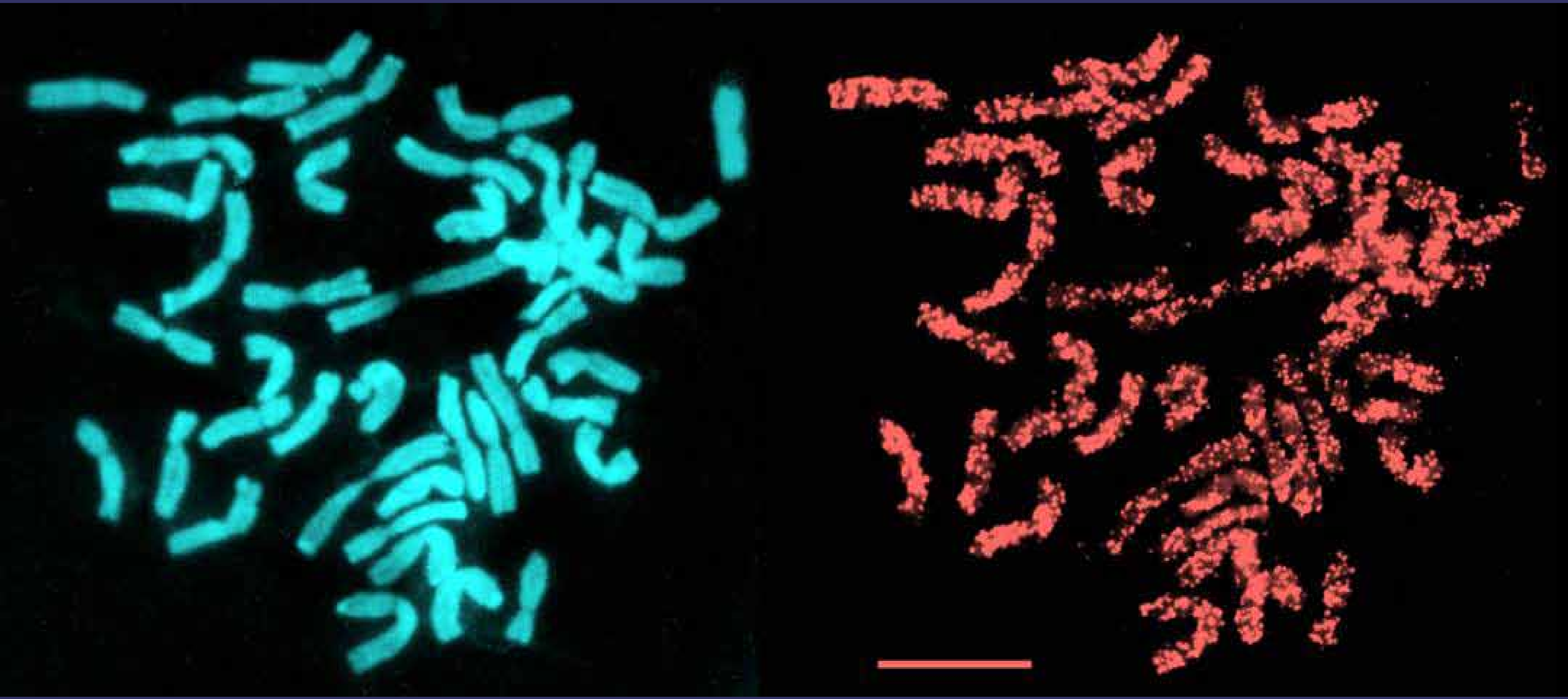
Similar with *copia* probe

Transcriptional Activity

Copia mRNA is present tissue culture
Analysis by RT-PCR
260bp product in some lines



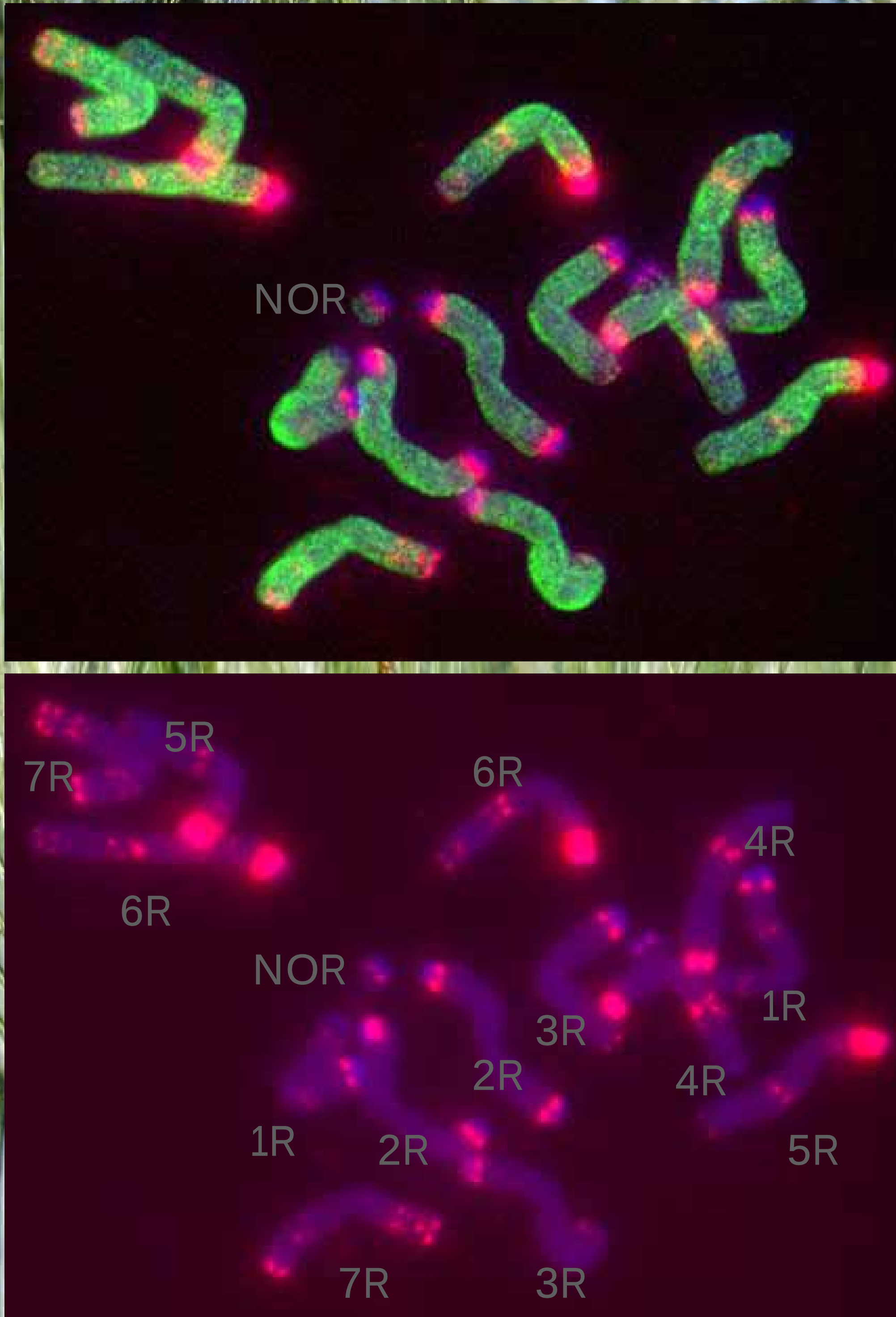
Modulation of Methylation
Anti-methylcytosine antibody



Evolution à Epigenetics à Development

Phenotype	Cause
Multiple abnormalities	Chromosomal loss, deletion or translocation
Genetic changes non-reverting	Gene mutation / base pair changes
	Telomere shortening
Changes seen, some reverting	Retro)transposon insertion
	Retrotransposon activation
	SSR expansion
	Methylation
(Male/Female) Normal Differentiation	Heterochromatinization
	Chromatin remodelling
	Histone modification

Rye genome (RR)



A. Contento and Schwarzacher

- uniform signal
- large sub-telomeric blocks only low methylation
- intercalary and small telomeric bands made of 120-bp repeat unit family are fully methylated
- **NOR region is not methylated**

DAPI

Anti-methylcytosine antibody

In situ hybridization with 120-bp repeat

Rye genome (RR) heavily methylated

- CpG sites methylated
- CpNpG sites less methylation
- Low-smeared signal with *Mcr*BC particular in the 120-bp repeat unit family

symmetrical

CCGG

M: *Msp*I

H: *Hpa*II

CCNGGG

B: *Bst*N1

S : *Scr*F1

uncut DNA

M: *Msp*I

H: *Hpa*II

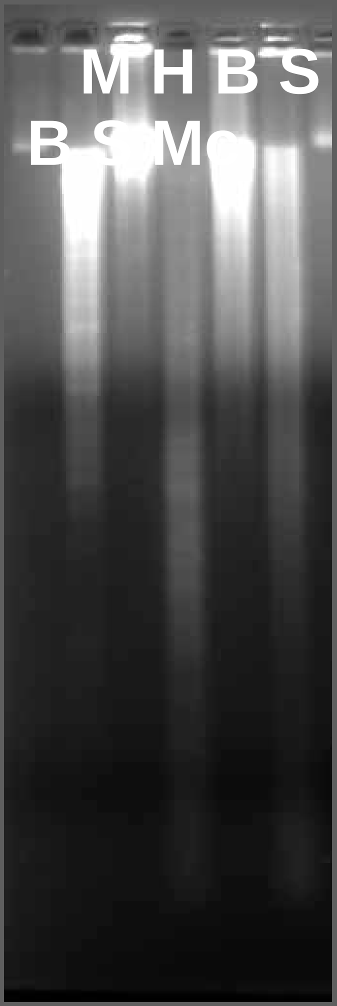
B: *Bst*NI

S: *Scr*FI

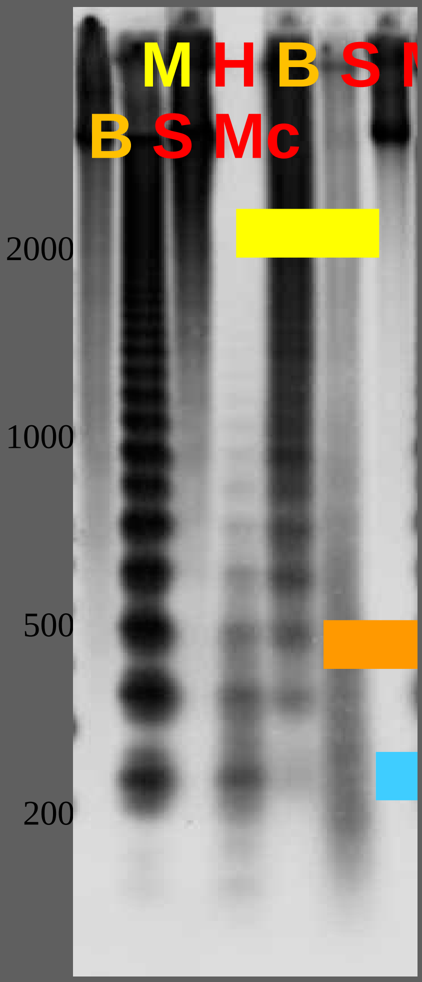
Mc *Mcr*BC

any mC cut

Genome



120bp repeat



Probe: Svav25/208-182

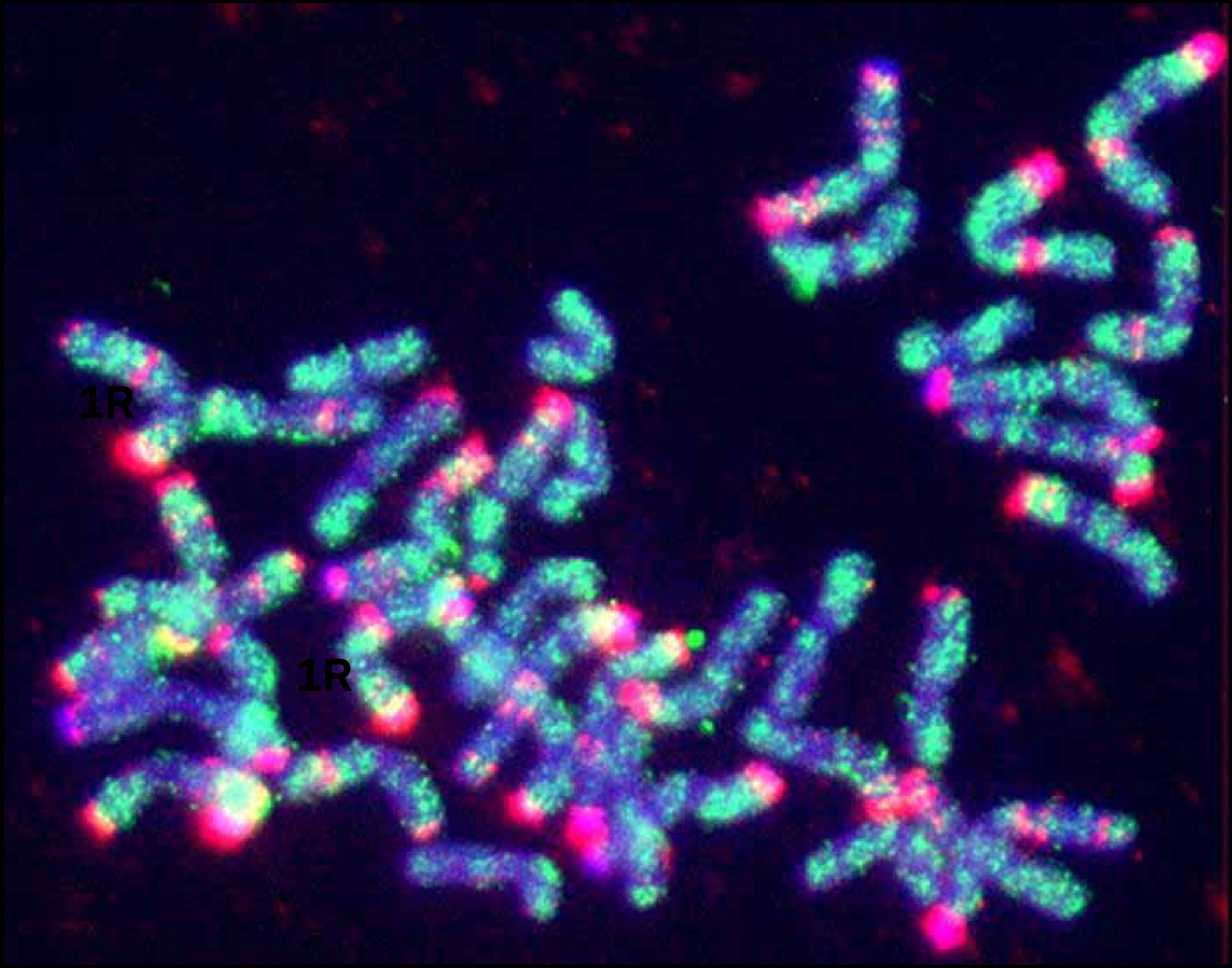
A. Contento and Schwarzacher

Triticale 'Fidelio' (AABBRR genome)

Uneven distributed signal in all genomes

Change of pattern in specific chromosomes and chromosomal regions

NOR of 1R is now methylated



DAPI

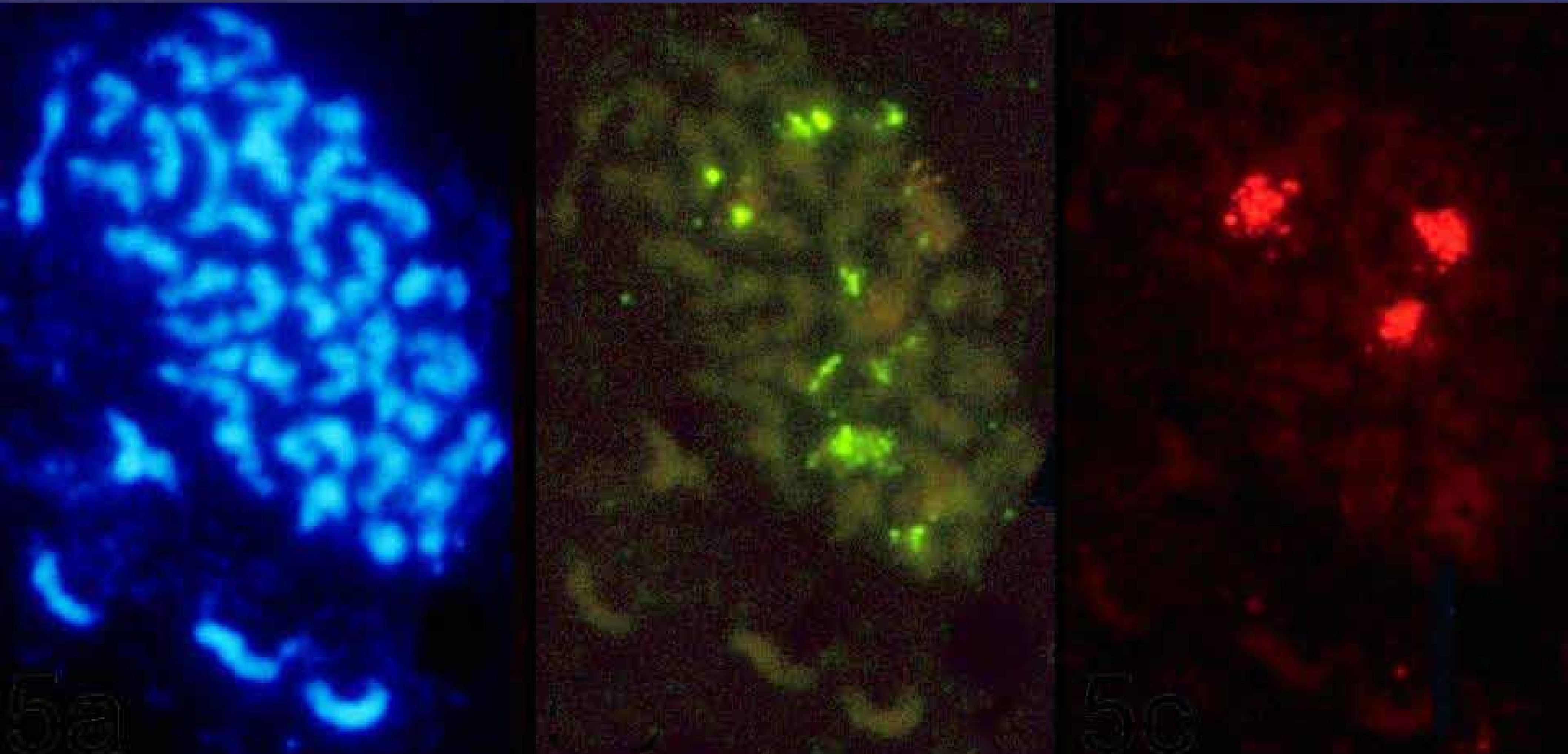
Anti-methylcytosine antibody *In situ* hybridization with 120-bp repeat

A. Contento and Schwarzacher

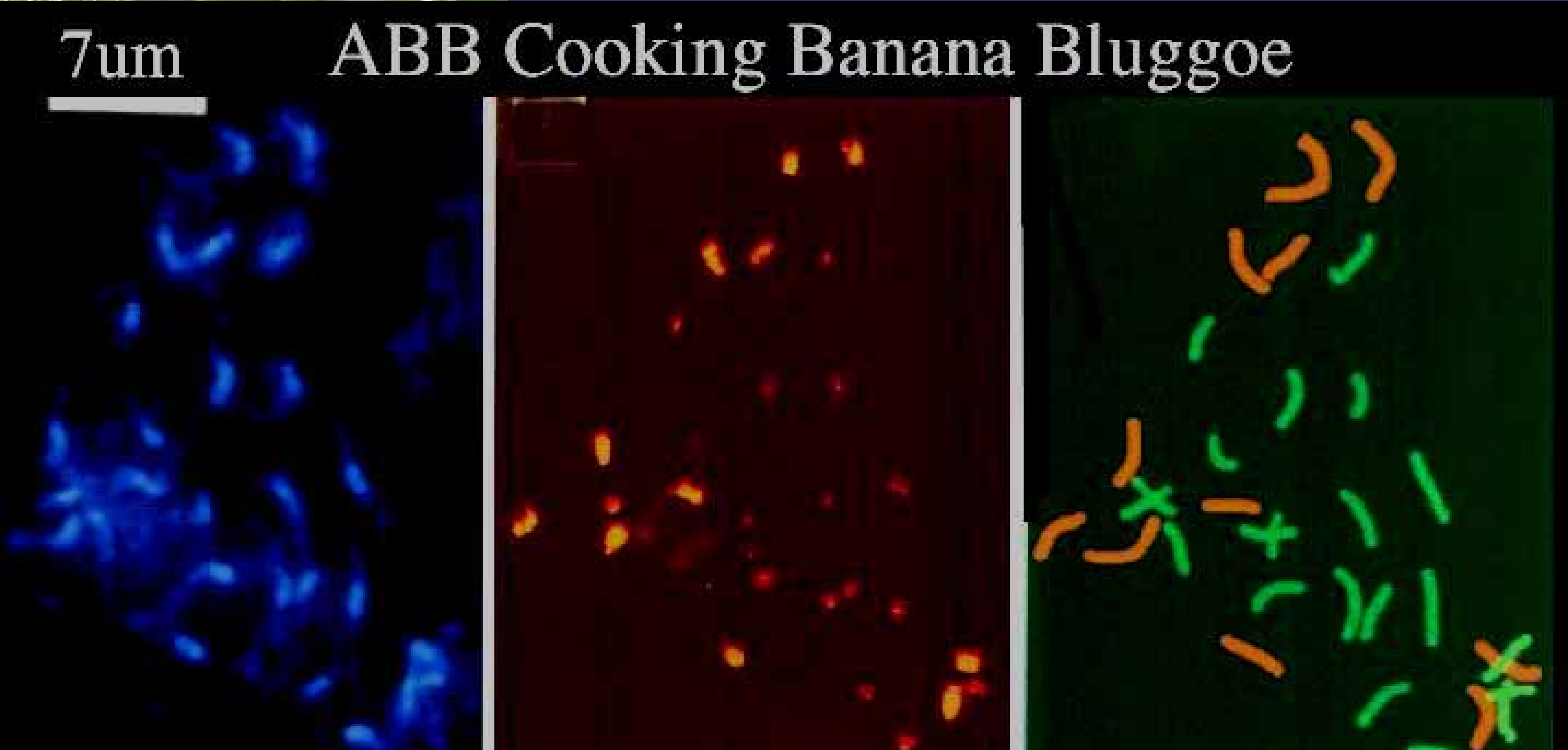

NSK
NSK

Cavendish : the most common dessert banana cultivar

2n=3x=33; AAA genomes



Cultivars are parthenocarpic, sterile triploids, 2n=3x=33
AAB and ABB plantains, cooking

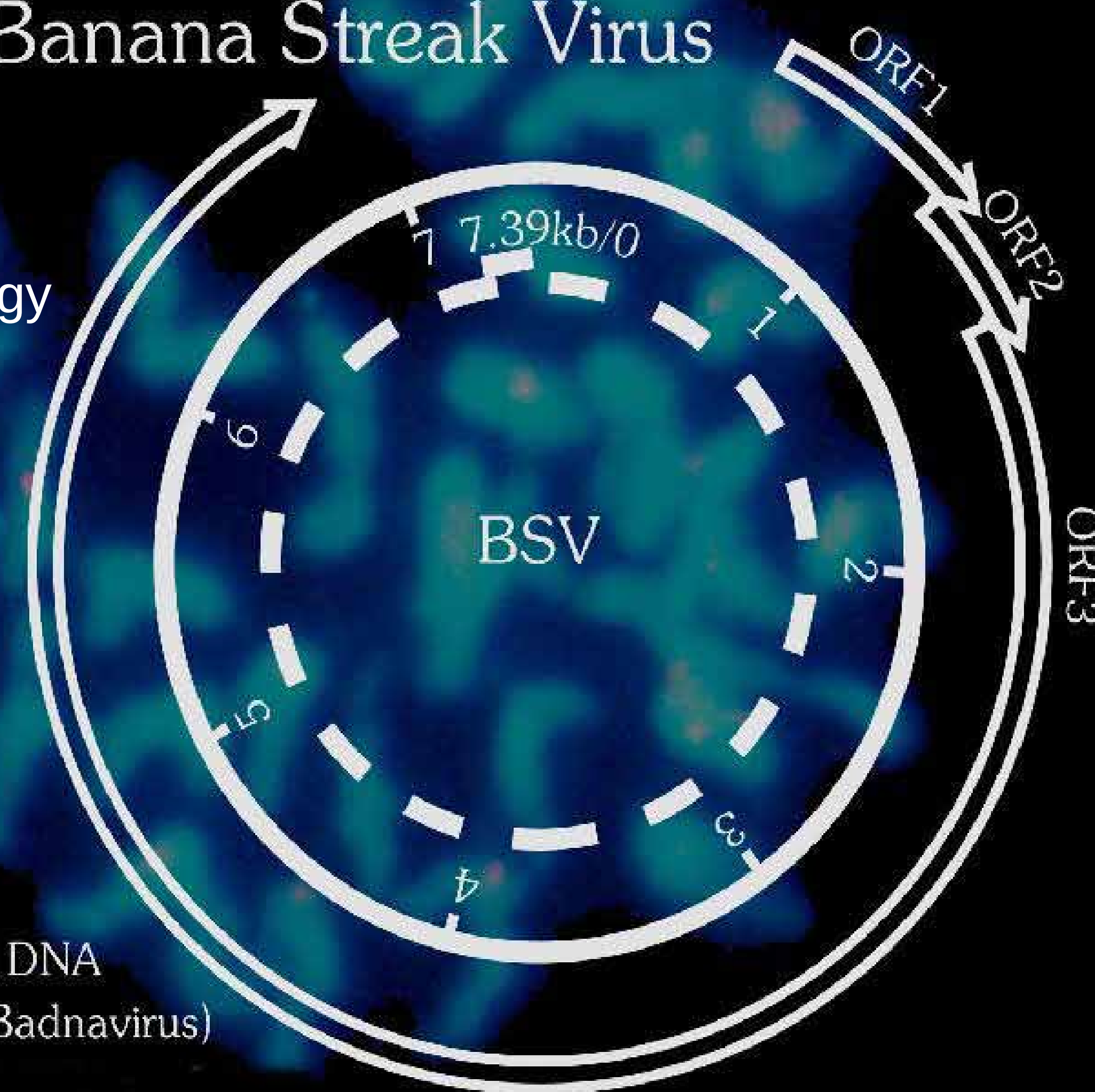


Banana Streak Virus

Unexpected epidemiology

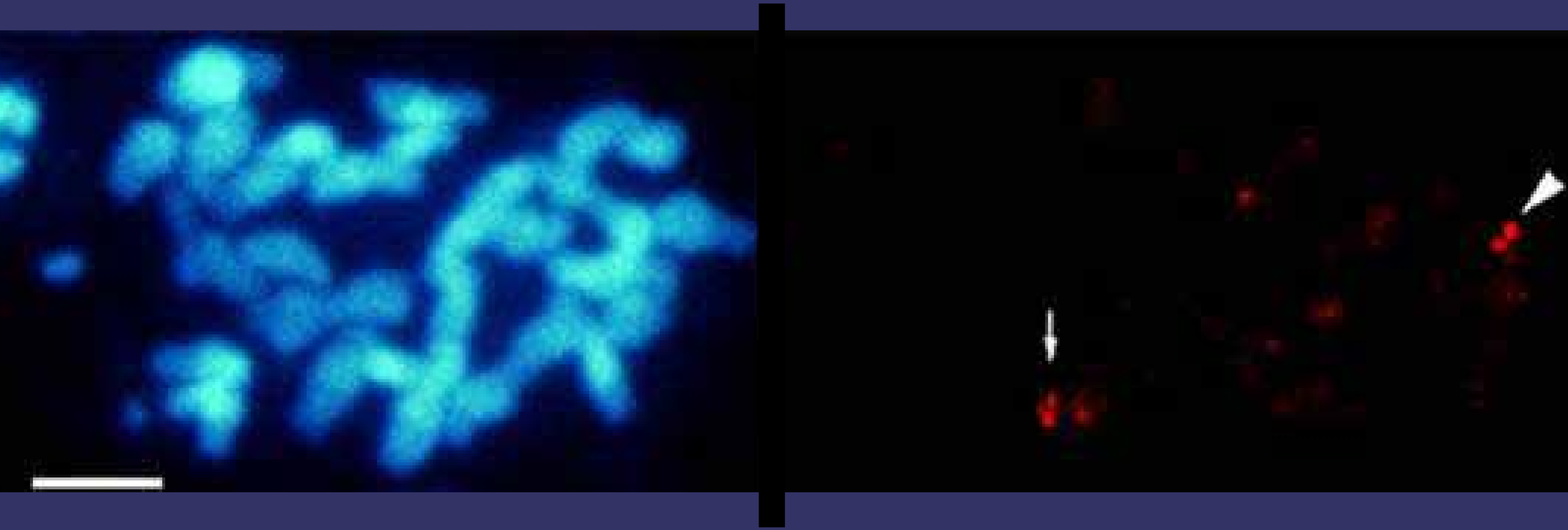
- No vector seen
- After cold nights
- After tissue culture

PCRs were often positive even in uninfected material



Double-stranded DNA
ParaRetrovirus (Badnavirus)

Nuclear Copies of BSV in Banana



Genomics, Banana Breeding and SuperDomestication

Traditional farmers:

- Grow the best plant they see
- Worked exceptionally well for banana
  - You see the best – parthenocarpic, large bunch

20th century breeding:

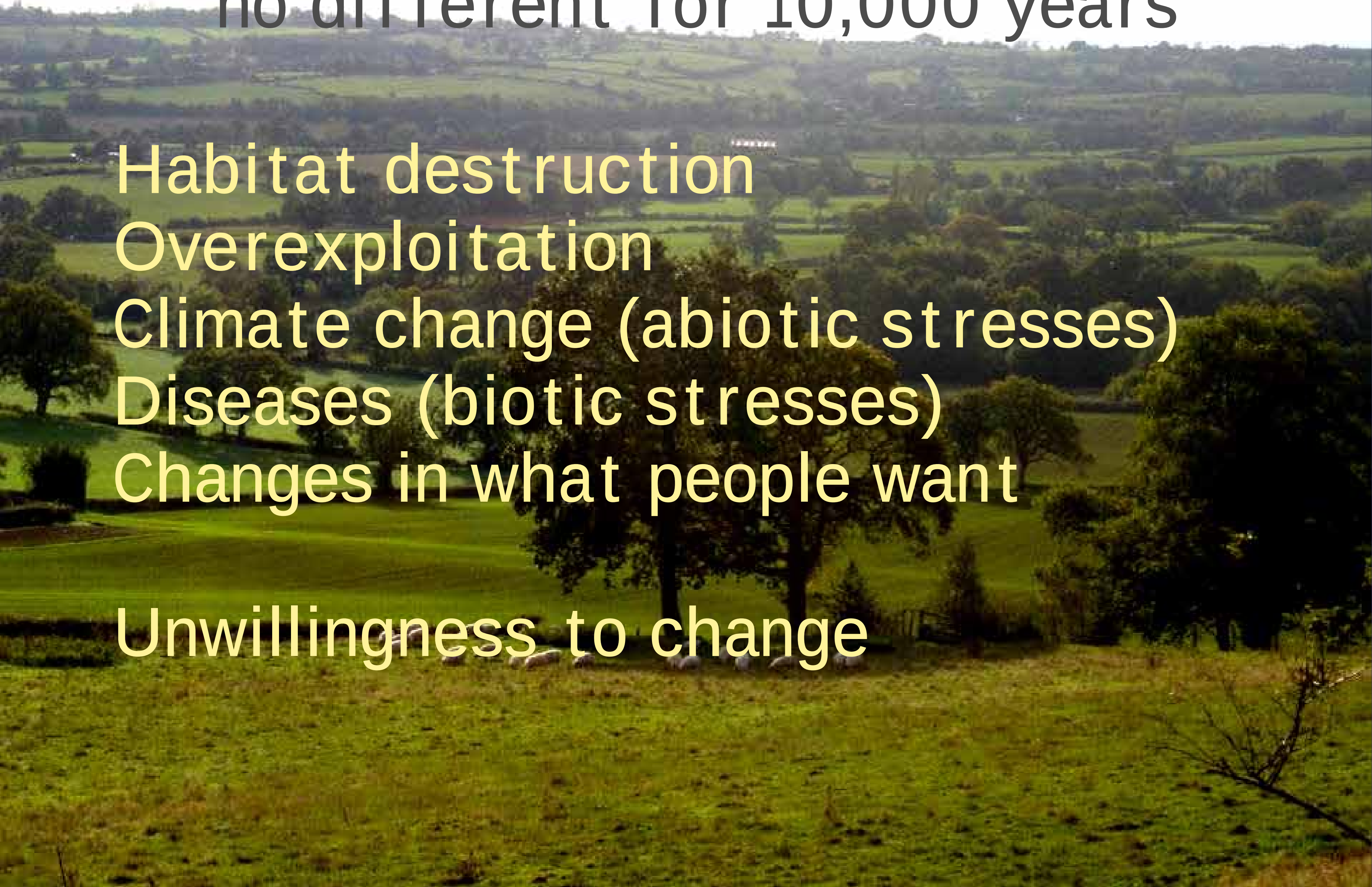
- Cross the best with the best
- Select something better in field trials
- Has largely passed banana by ...

We need "Novel approaches to understanding, conserving and using banana genetic diversity"

Challenges

- Production
- Environment (abiotic stresses)
- Disease (biotic stresses)
- Post-harvest (uses, distribution)
- Markets and livelihoods

Threats to sustainability: no different for 10,000 years



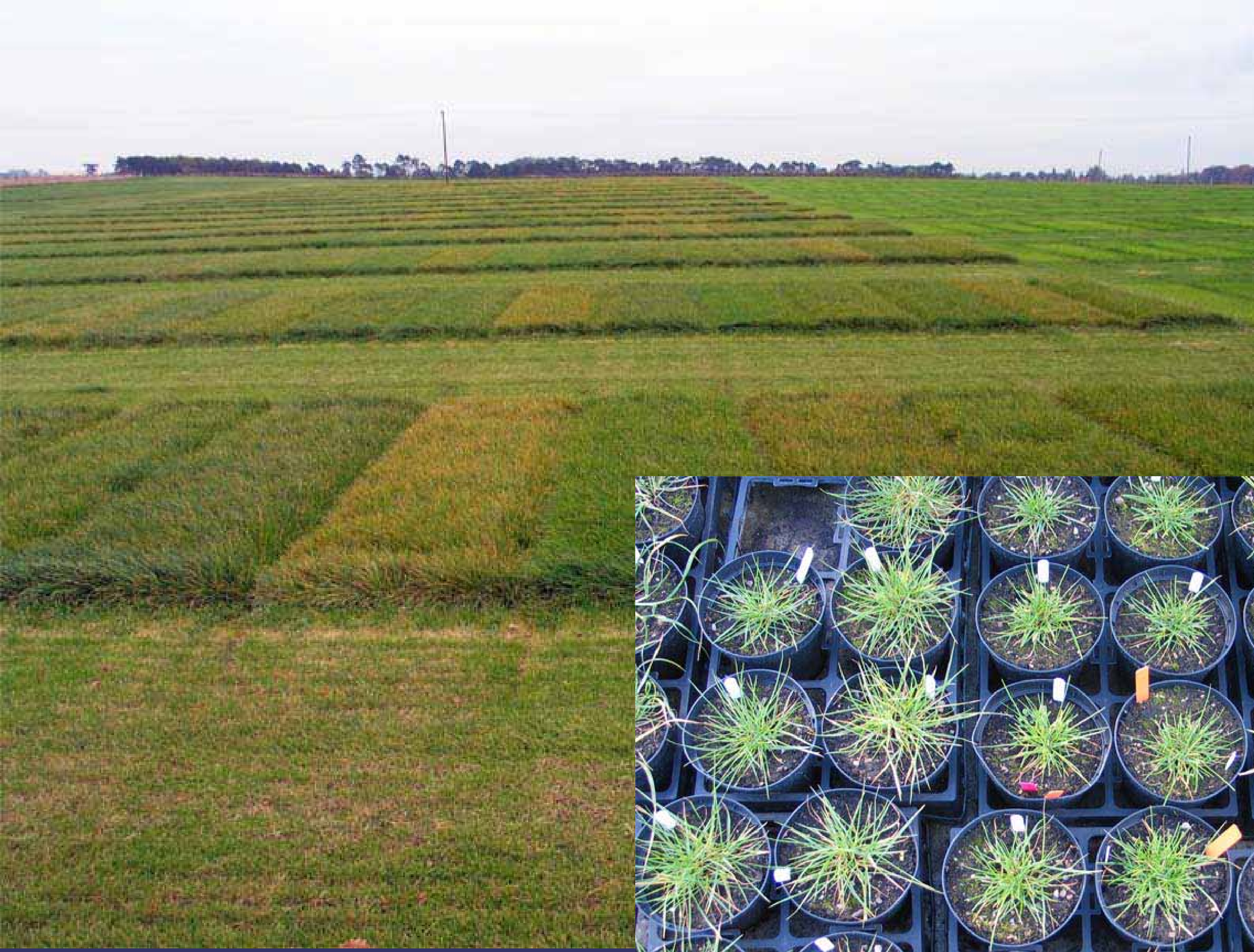
Habitat destruction
Overexploitation
Climate change (abiotic stresses)
Diseases (biotic stresses)
Changes in what people want

Unwillingness to change

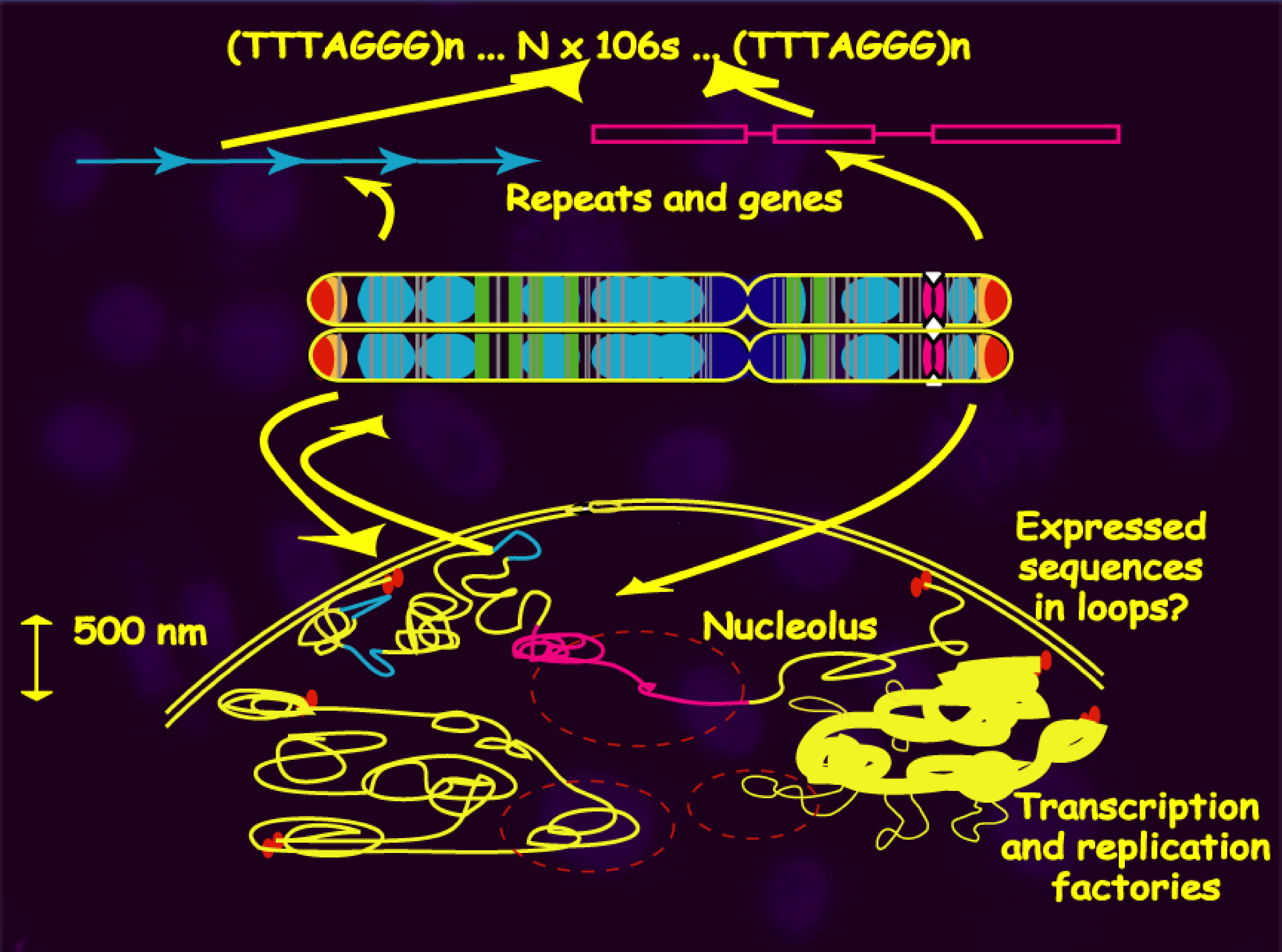
SuperDomestication

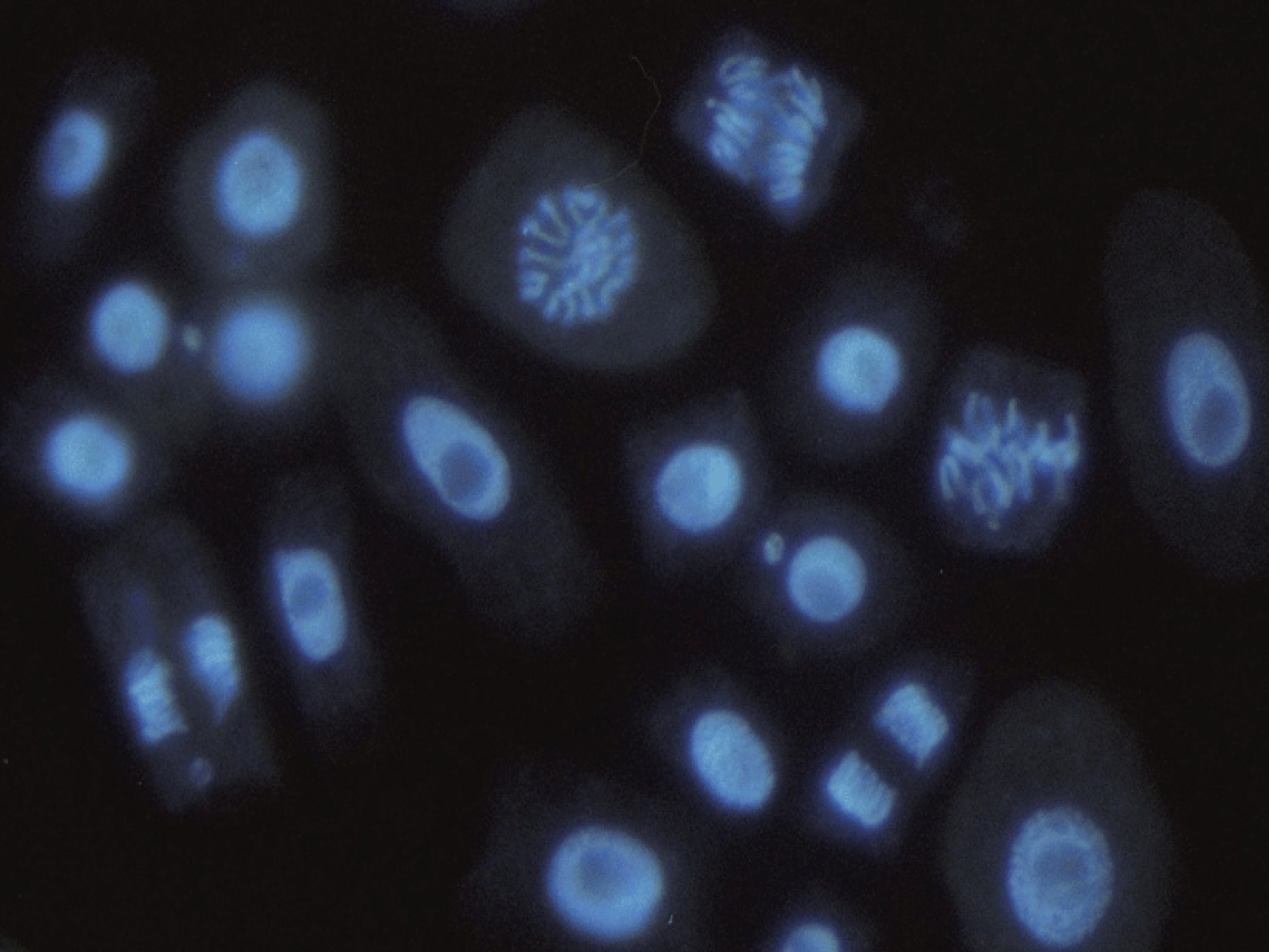
- Setting the targets
- Finding the answers (genes) to meet the targets
- Applying the appropriate technologies to use the genes
  - Crossing strategies or transfer
  - Marker assisted selection

Anhalt, Barth, HH in press 2009



Anhalt, Barth, HH et al. Segregation distortion in Lolium: evidence for genetic effects. Theoretcial & Applied Genetics 2008


(TTTAGGG)n ... N x 106s ... (TTTAGGG)n
Repeats and genes
500 nm
Expressed sequences in loops?
Nucleolus
Transcription and replication factories



This problem of the conversion of varieties into species,—that is, the augmentation of the slight differences characteristic of varieties into the greater differences characteristic of species and genera, including the admirable adaptations of each being to its complex organic and inorganic conditions of life,—will form the main subject of my second work.

the whole subject of variation under domestication. We may thus hope to obtain some light, little though it be, on the causes of variability,—on the laws which govern it, such as the direct action of climate and food, the effects of use and disuse, and of correlation of growth,—and on the amount of change to which domesticated organisms are liable. We shall learn something on the laws of inheritance, on the effects of crossing different breeds ... During this investigation we shall see that the principle of Selection is all important. Although man does not cause variability and cannot even prevent it, he can select, preserve, and accumulate the variations given to him by the hand of nature

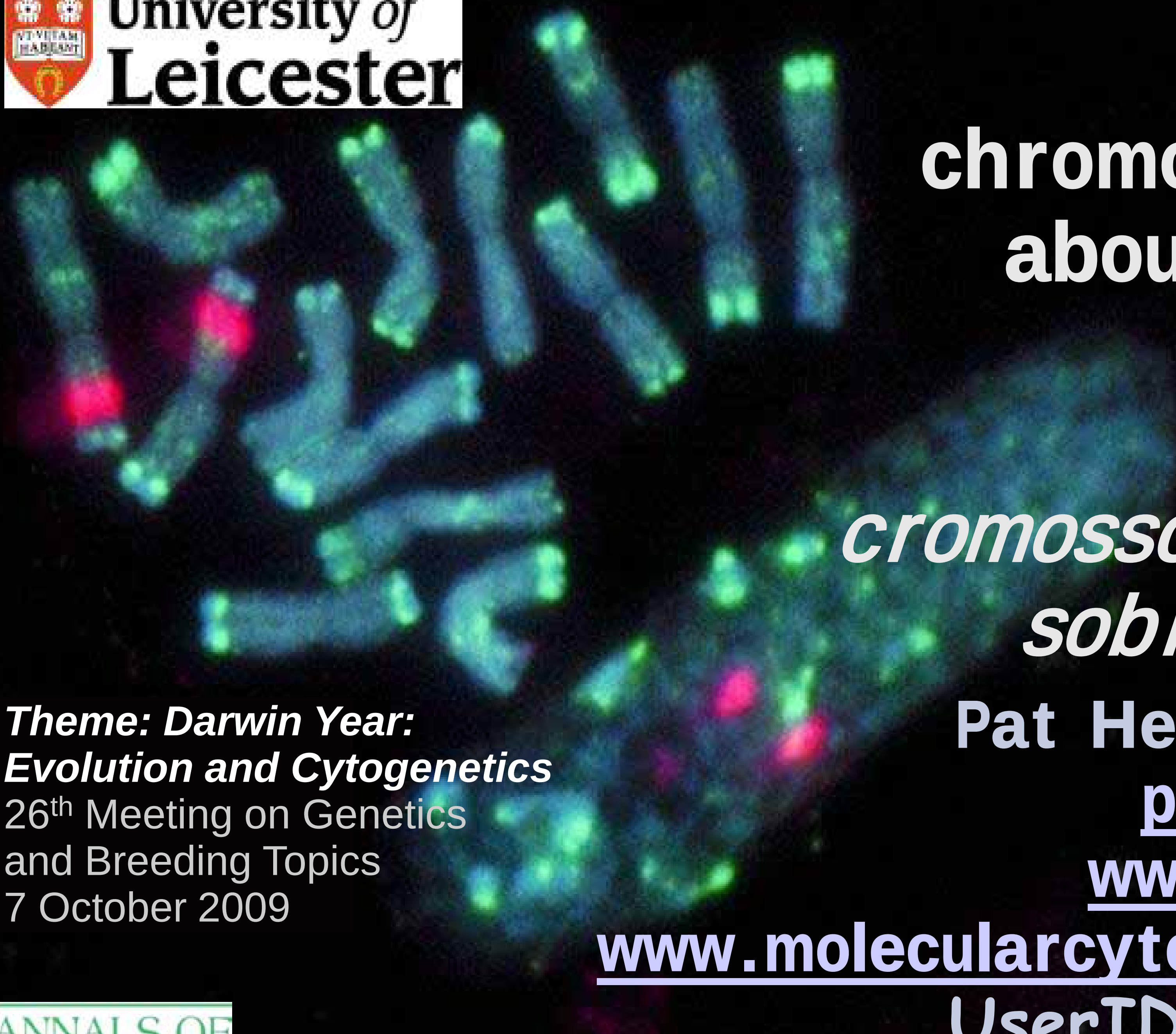
United Nations
Millennium Development Goals

- Goal 1 – Eradicate extreme poverty and hunger
- Goal 2 – Achieve universal primary education
- Goal 3 – Promote gender equity and empower women
- Goal 4 – Reduce child mortality
- Goal 5 – Improve maternal health
- Goal 6- Combat HIV/AIDS, malaria and other diseases
- Goal 7 - Ensure environmental sustainability
- Goal 8 - Develop a global partnership for development

Molecular Cytogenetics and Darwin

- Diversity in the species
- Cytogenetics and genomics
- Wide hybrids and recombination
- Epigenetics and genome interactions
- Breeding achievements
- The genepool to address challenges

Superdomestication



What the chromosomes say about evolution

O que os cromossomos dizem sobre evolução

Pat Heslop-Harrison
phh4@le.ac.uk
www.molcyt.com
www.molecularcytogenetics.com
UserID/PW: 'visitor'

Theme: Darwin Year: Evolution and Cytogenetics

26th Meeting on Genetics and Breeding Topics
7 October 2009

University of Leicester

ANNALS OF BOTANY

Genomics ...

- The genepool has the diversity to address these challenges ...
- New methods to exploit and characterize germplasm let use make better and sustainable use of the genepool

FINANCIAL TIMES

From Prof Donald Braben and others.

Sir, We the undersigned scientists write to draw attention to a neglected aspect of the current economic crisis. Robert Solow won the Nobel Prize in economics in 1987 for his 1950s discovery that *technical change* was the biggest source of growth, a discovery that seems to have been forgotten.

Scientific advances are not predictable.

University, Nobel laureate
Pat Heslop-Harrison, University of Leicester
Steve Howdle, University of

Economic growth stems from "technical change" rather than the trinity of capital, resources and labour

The reliable route to technical change is science

Future – Crop production changes

	1961	2005	inc
Oil Palm Fruit	13,669,750	173,261,199	12.67479
Soybeans	26,882,808	209,531,558	7.794259
Tomatoes	27,617,540	124,748,292	4.516995
Citrus Fruit,Total	24,999,430	105,431,984	4.217376
Maize	205,004,683	692,034,184	3.375699
Bananas+plantains	34,182,417	105,872,483	3.097279
Sugar Cane	447,977,522	1,293,220,050	2.886797
Cassava	71,262,039	203,863,208	2.860755
Rice, Paddy	215,654,697	614,654,895	2.850181
Wheat	222,357,231	626,466,585	2.817388
People	3,081,748,662	6,451,058,790	2.093311
Barley	72,411,104	138,267,192	1.909475
Sugar Beets	160,501,987	241,985,317	1.507678
Sweet Potatoes	98,192,635	129,888,827	1.322796
Potatoes	270,552,196	321,974,152	1.190063