Evolution of chromosomes and genomes

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Chromosome rearrangements

Inversion

Translocation

Transposition

Tetraploidy

Additional question: when these occur they are rare in a population: how do they spread?
Chironomus banded chromosomes

Fig. 4.1. The four polytene elements from a salivary gland nucleus of Chironomus thummi, showing the banding. Small arrows indicate the approximate positions of the centromeres. The shortest chromosome has its longer arm largely heterochromatic and the other three elements have short heterochromatic regions at the tips. From Bauer (1935).
Banding pattern changes

in two species of Chironomus midges

Fig. 11.12. Comparison of the banding pattern in chromosome arm IIR of Chironomus piger (left) and C. thummi (right) in the hybrid between them. Bands C2.11 and C2.4 show a two-fold increase in DNA content in thummi, band C2.12 shows a four-fold increase, bands C2.2, C2.1 and C1.9 show the same amount. In the case of bands C2.3, C1.11, C1.8, C1.7 and B5.28 the increase is variable. From Keyl (1965).
Polytene Drosophila chromosomes
Chromosome phylogeny of Drosophila pseudoobscura etc.

FIGURE 5.2
Phylogenetic relationships of the gene arrangements in the third chromosomes of Drosophila pseudoobscura, D. persimilis, and D. miranda.
Chromosome phylogeny of Hawaiian Drosophila
Formation of the Hawaiian islands

plate

hot spot
Geology of the Hawaiian islands
Inferred migration events on the Hawaiian islands

Figure 5.—Geographical summary of the proposed founder events invoked to explain the origin of the fauna of each island. The width of the arrows is proportional to the number of proposed founders. The number of species found on each island is given in parentheses.
Paracentric and pericentric inversions

A Paracentric Inversion

A Pericentric Inversion
Pairing in a paracentric inversion heterozygote
Crossing-over in a paracentric inversion heterozygote
Pairing in a pericentric inversion heterozygote
Crossing-over in a pericentric inversion heterozygote
A translocation

Before

A B C D E F G H I J

Breaks

A B C D E F G H I J

Rearrangement

Q E F G H I J

After

Q E F G H I J

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Segregation of translocation heterozygote

at first division of meiosis metaphase

A pair of translocated chromosomes

pairs with a pair of untranslocated chromosomes
Adjacent segregation in translocations

... Leads to deletions and duplications.
Alternate segregation in translocations

... Leads to euploid (normal gene complement) gametes
The fern Ophioglossum, high number champion

Fig. 2.11 Meiotic prophase (diakinesis) in a sporocyte of *Ophioglossum reticulatum*, showing about 630 bivalents. (From Ninan.)
The ant *Myrmecia*, low chromosome number champion

Fig. 1. Chromosomes from prepupal cerebral ganglia. (A) Worker prometaphase chromosomes. Identical C-banding provides evidence for homology of the two chromosomes. (B) Male prometaphase chromosome. Chromosomes consistently display a large centromeric C-band on the short arm and a smaller centromeric C-band on the long arm. Most of the short-arm C-band is not immediately adjacent to the centromere, though a very small portion of the short-arm C-band is centromeric. Arrows indicate position of centromere.
Distribution of chromosome numbers in mammals
Karyotypes of Drosophila species

Fig. 11.3. Male karyotypes of some members of the subgenus Sophophora of Drosophila. Several different karyotypes have been reported for montium and takahashii. Based on various authorities.
Karyotypes of gymnosperms

Fig. 4.12  Karyotypes of various genera of gymnosperms. (a) *Pinus*, showing the symmetrical karyotype characteristic of the families Pinaceae, Cupressaceae, and most genera of Taxodiaceae. (b), (c). Moderately asymmetrical karyotypes of *Amentotaxus argyrotaenia* (Taxaceae) and *Stangeria paradoxa* (Cycadaceae). (d), (e), (f). Strongly asymmetrical karyotypes of *Podocarpus nivalis* (Podocarpaceae), *Ginkgo biloba* (Ginkgoaceae), and *Welwitschia mirabilis* (Welwitschiaceae). (a) from Bowden; (b) from Chuang and Hu; (c) from Marchant; (d) from He and Bouck; (e) from de Vries; (f) from Korol.
Mouse and human maps compared

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(this shows only the larger homologies)

Courtesy Lisa Stubbs
Oak Ridge National Laboratory
Polyploid species

A tetraploid

Gametes

Triploid offspring

An ordinary diploid

Gametes

The resulting aneuploid offspring
Polyploid evolution in Clarkia
How it was done

This projection produced

- using the \texttt{prosper} style in LaTeX,
- using Latex to make a .dvi file,
- using \texttt{dvips} to turn this into a Postscript file,
- using \texttt{ps2pdf} to mill a PDF file, and
- displaying the slides in Adobe Acrobat Reader.

Result: nice slides using freeware.