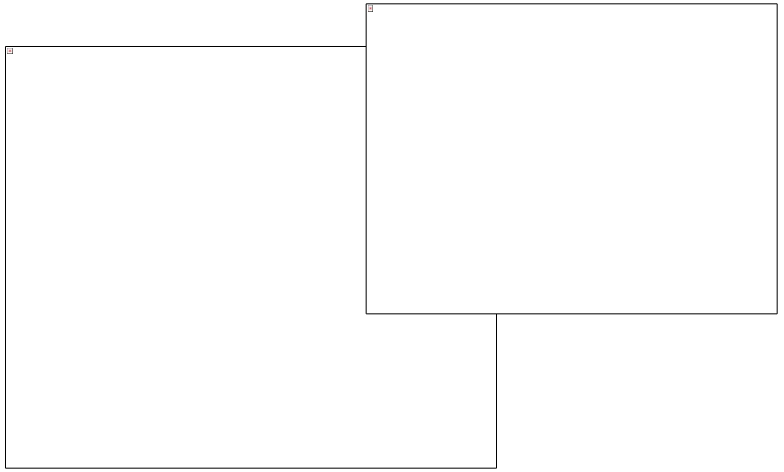
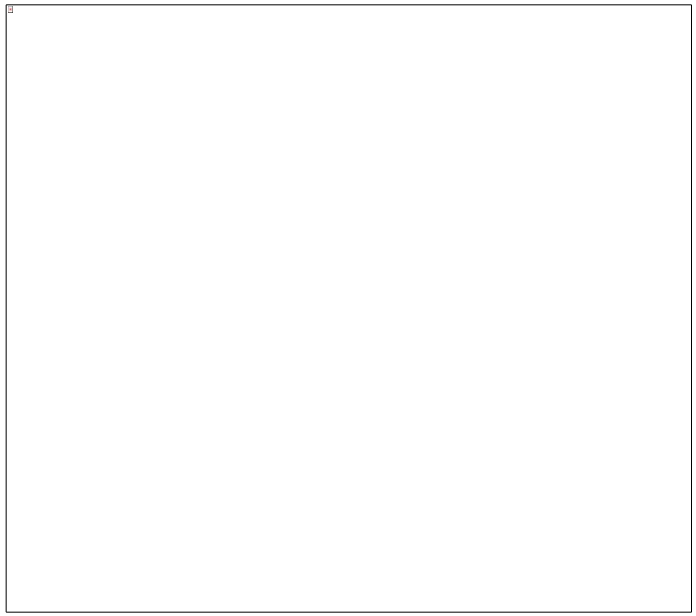
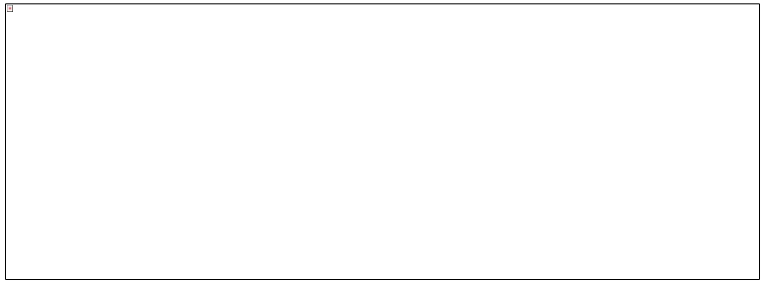
The plant of the day

- *Musa acuminata (Musa balbisiana)*
- >1000 species of bananas
- Cavendish banana-AAA triploid (replaced the 'Gros Michel')
- Plagued by the Panama disease (Fusarium wilt)







Questions

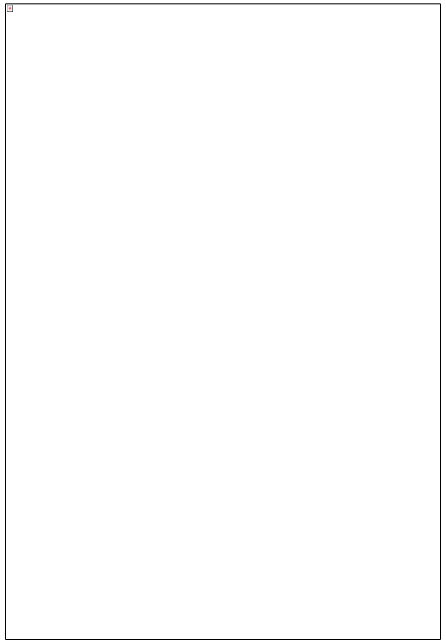
Why is polyploidy more frequent in plants than in animals?

Is polyploidy an evolutionary dead end?

What is the evolutionary fate of duplicate genes and genomes?

Polyploid Speciation

Speciation via whole genome duplication



Outline:

What is polyploidy?

How does it happen?

How common is it?

What are the different types of polyploidy?

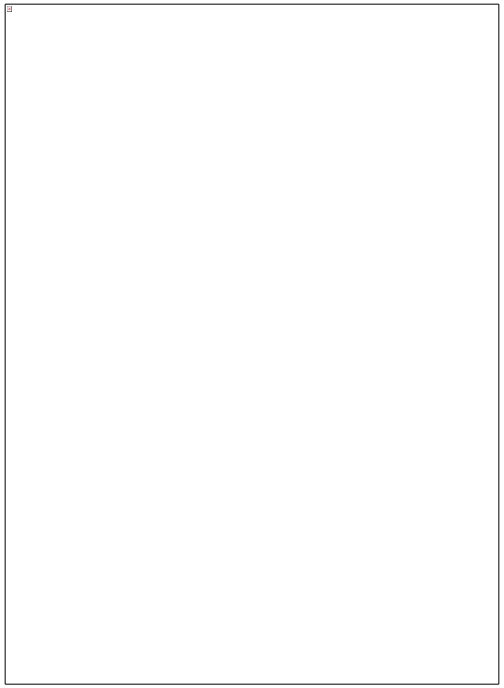
What are the advantages and disadvantages?

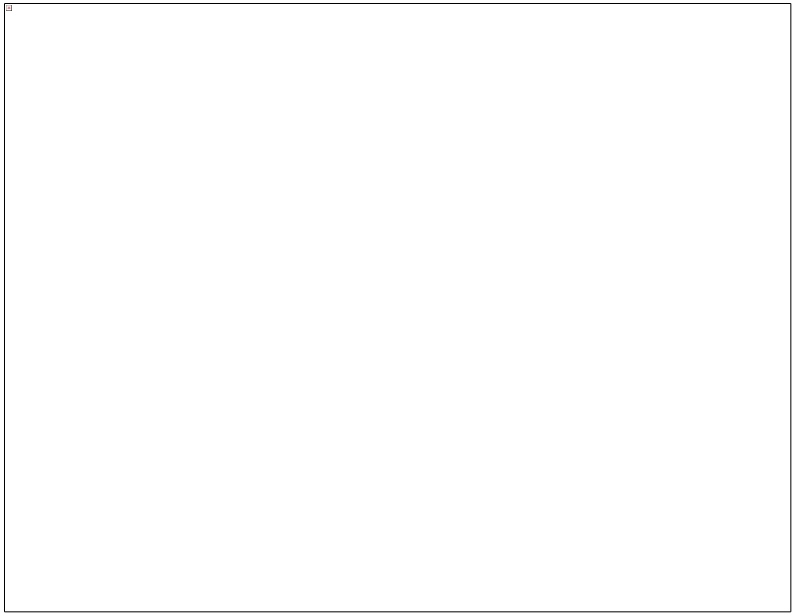
How do polyploids establish?

What is polyploidy?

What is polyploidy? - the condition in which a normally diploid cell or organism acquires one or more additional sets of chromosomes

How can polyploids be identified? – changes in chromosome number, genome number, cell size, stomata size, flower size, and flowering time



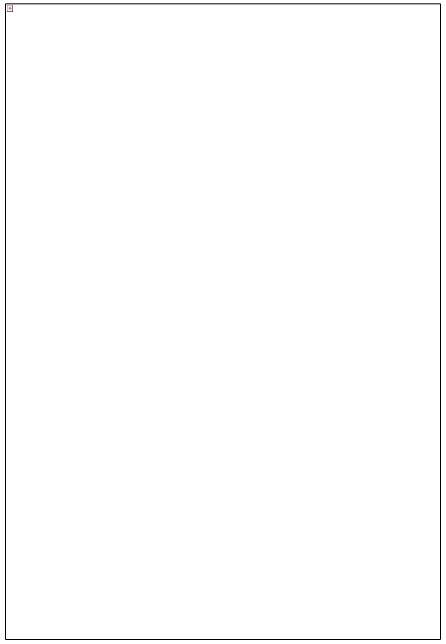


What are the two main types of polyploidy?

Autopolyploidy: “self” duplication – whole genome duplication within single species

Allopolyploidy: “other” duplication – whole genome duplication combined with hybridization of two species

The distinction can be unclear



How can polyploidy arise?

Fusion of unreduced gametes

Somatic mutation

Triploid bridge

What pathways to polyploidy are most common?

How can we identify auto- and allopolyploids?

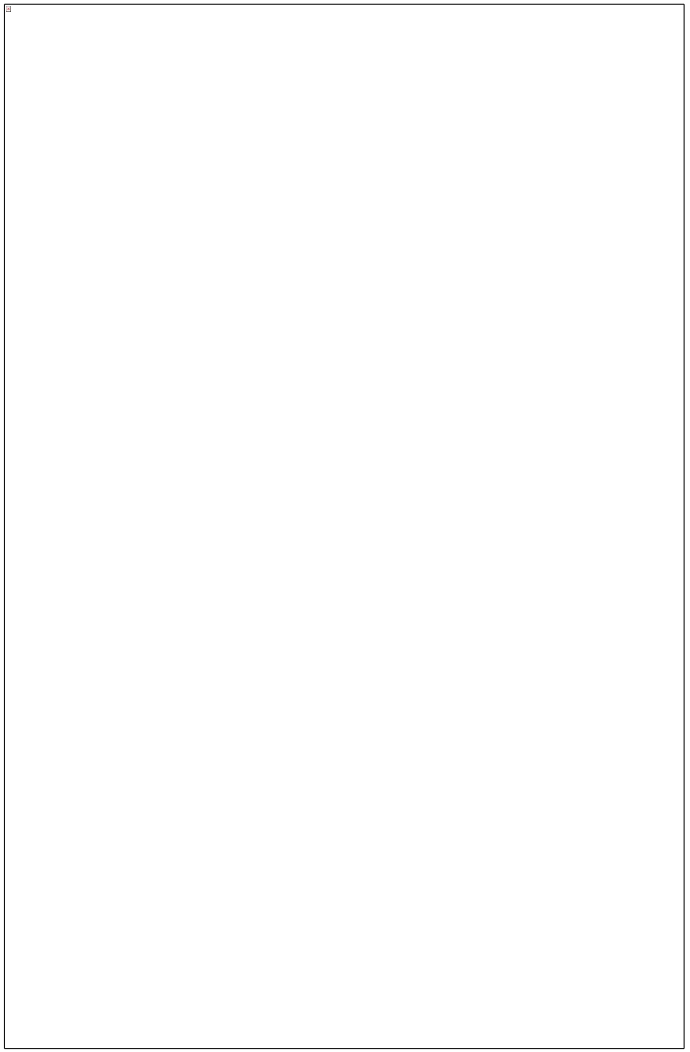
Autopolyploids typically have multivalent pairing

-chromosomes are more or less identical (polysomic inheritance)

Allopolyploids are variable

-bivalent pairing with more genetic divergence (disomic inheritance)

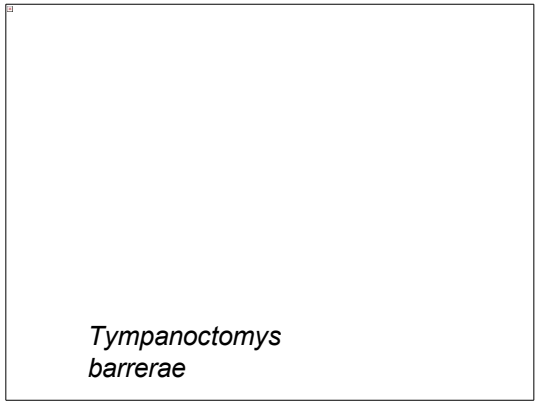
-multivalent pairing when closely related



How common is polyploidy?

Common in plants, amphibians and fish

Rare in higher vertebrates



Tympanoctomys barrerae

Causes 10% spontaneous miscarriage in humans

Evidence for whole genome duplication in history of all angiosperms

Autotetraploid formation 10^{-5} (flowering plants)

How often does polyploid speciation occur in plants?

Polyploid incidence and speciation frequencies across major groups of vascular plants

Wood T E et al. PNAS 2009;106:13875-13879

How often does polyploidy affect diversification rates?

Recently Formed Polyploid Plants Diversify at Lower Rates, Volume: 333, Issue: 6047, Pages: 1257-1257, DOI: (10.1126/science.1207205)

What is the frequency of auto- vs allopolyploid speciation?

Hard to assess

- autopolyploids often cryptic and undescribed
- 8 – 9 % of plant species contain multiple cytotypes

Bioinformatic analysis suggests 86% of polyploids are allopolyploids

What are some advantages of polyploidy?

Heterosis

Gene redundancy

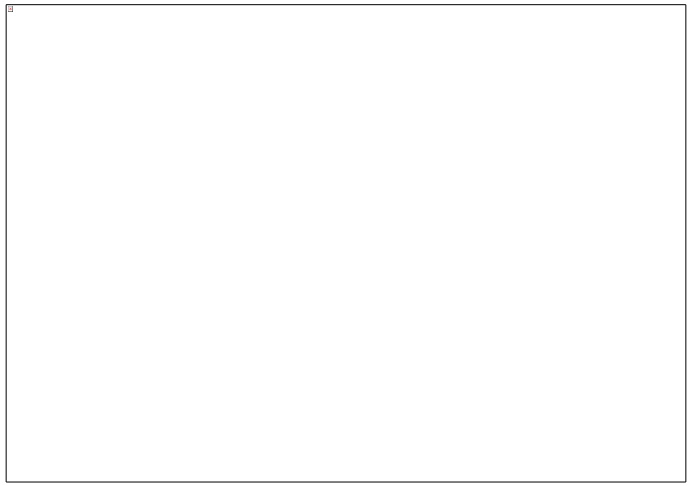
Selfing and asexuality (often associated)

Heterosis

What is heterosis?
The increase in performance displayed by hybrids (traits of the F1 transgress parental values)

What causes heterosis?
Heterozygosity (heterozygote advantage, recessive deleterious alleles)

How is heterosis maintained by polyploidy?
Bivalent pairing of homologs (allopolyploids)



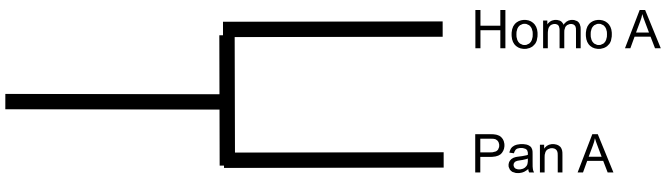
Gene redundancies and genetic buffering

More than one copy of each allele in gametes

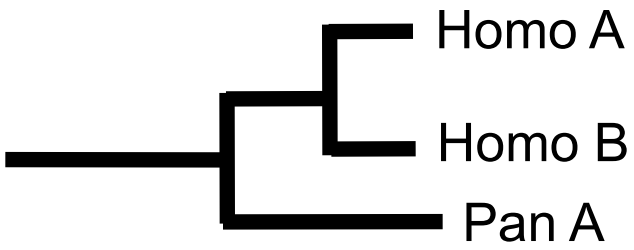
Changes in function of duplicated genes

Duplicate Genes are a Source of Novelty

Homology = Similarity because of common descent



Ortholog = Homologous genes that have diverged because of lineage divergence



Paralog = homologous genes that have evolved via duplication

The fate(s) of duplicate genes

Force *et al* 1998

Gene duplication can lead to genetic incompatibilities

Burke and Arnold 2001

What are some potential disadvantages of polyploidy?

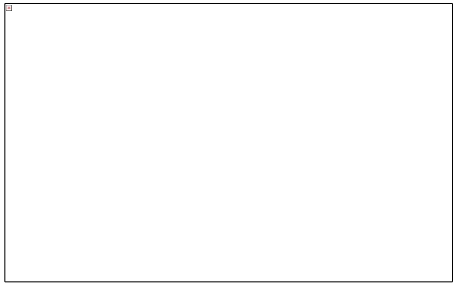
Discussion

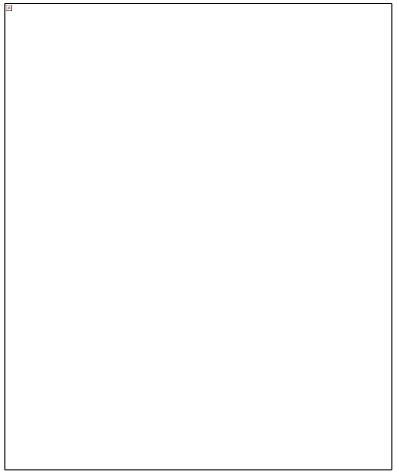
What are some potential disadvantages of polyploidy?

Changes in cellular architecture
(increase in cell size, imbalance in gene dosage)

Problems with mitosis and meiosis
-can produce aneuploid cells
(particularly with multivalent pairing, triploids)

Changes in gene expression, TE proliferation





How do ploidy differences result in reproductive isolation?

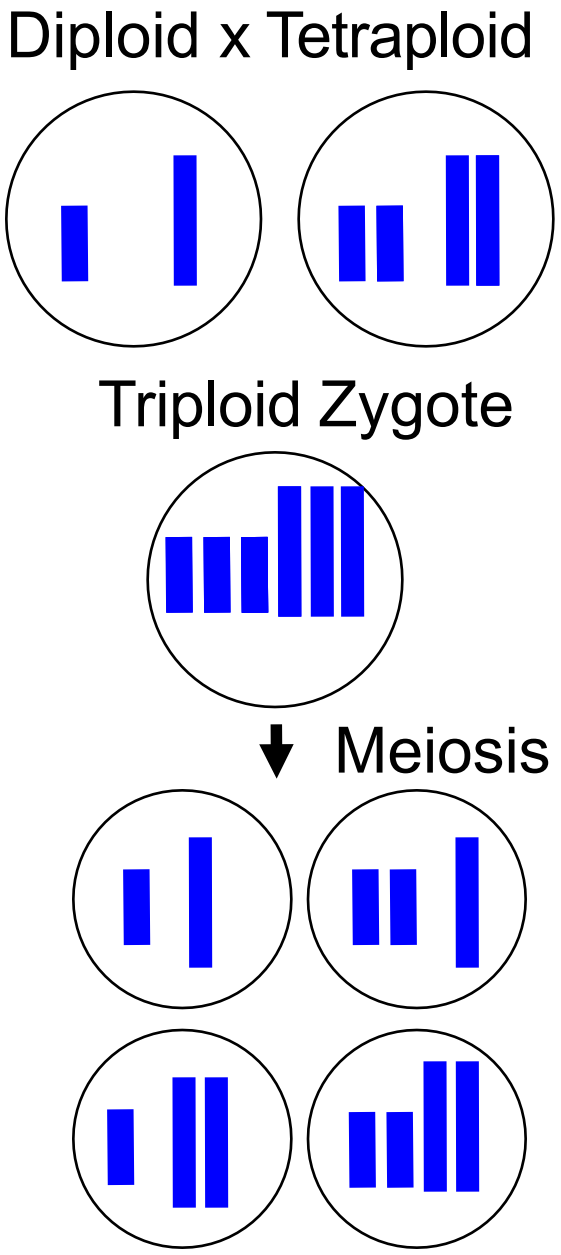
Substantial reproductive isolation between parents and polyploids

~ 95% of triploid seed set inviable

- more chromosomes = more aneuploidy = more deleterious

Frequently low fitness of triploids

Can help maintain polyploid species



What are major challenges to polyploid establishment?

Niche overlap and competition with parent(s)

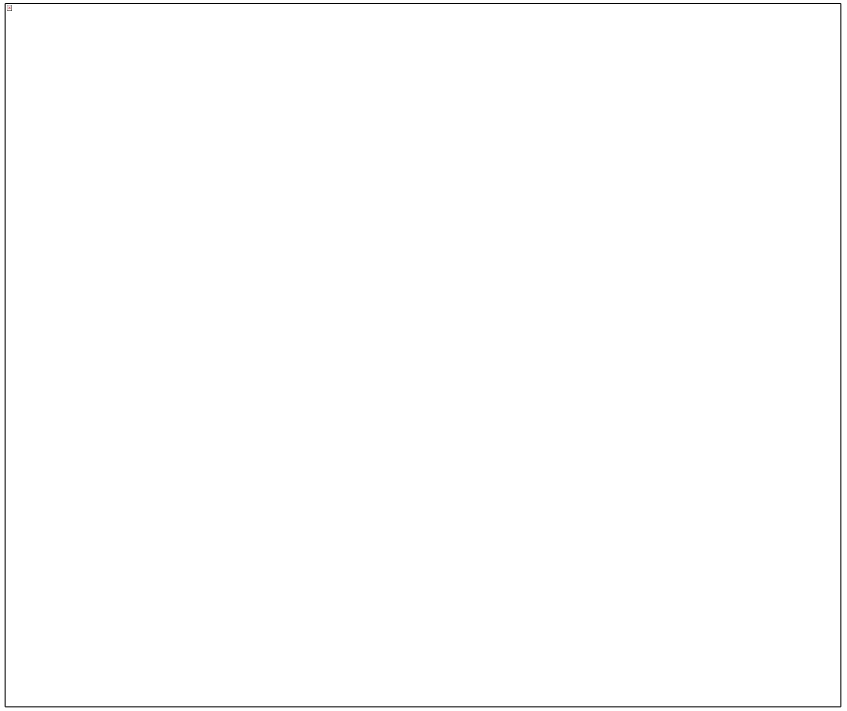
Minority cytotype disadvantage (Levin 1975)

-post zygotic isolation

-e.g. most 2x gametes lost to 1x gametes

Reduced fertility of nascent polyploids mostly due to meiotic irregularities

-can recover quickly

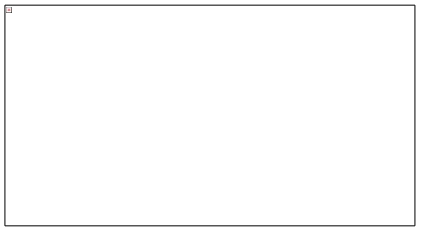


Ramsey and Schemske 2002

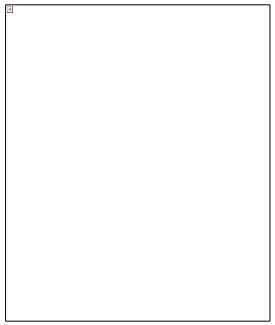
Is there niche differentiation between ploidy levels?

Greater variation in polyploids (wider array of habitats)

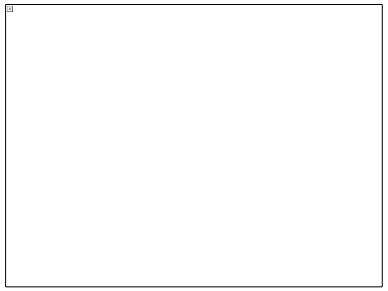
e.g. strawberry



Intermediate habitats e.g. *Antennaria rosea*



Separate ranges e.g. *Tolmiea menziesii*



Are differences a consequence polyploidy or have they arisen after polyploidization?

How do polyploids overcome their initial numerical disadvantage?

Parent species sometimes contribute to polyploid gene pool

Recurrent polyploid formation increases population size and genetic diversity

Uniparental reproduction

Fertility also increases over time with genomic stabilization

Surviving Sympatry

Selfing

Polyploid Advantage

Local dispersal

Baack 2005

What happens to the genome of new polyploids?

Rapid genome reorganization
(e.g. *Brassica, Avena sativa, Nicotiana tabacum*)

Sequence elimination

Genomic downsizing

Gene silencing: gene loss, epigenetics and subfunctionalization

Diploidization

Unanswered Questions

What explains variation in polyploid speciation rates in different plant groups?

Do allopolyploids have higher diversification rates that autopolyploids?

Do hybrid incompatibilities arise more quickly in polyploids than diploids?

Are polyploids less effected by inbreeding depression and genetic load than diploids?

Is there a fitness disadvantage associated with too many chromosomes and/or too much DNA?